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OLDMISS Algorithm Analysis

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16. Abstract

The OLDMISS computer program is used to estimate the ΔV's of vehicles in a collision, when the damage to one of the vehicles is unknown. The program estimates the energy dissipated in the structure of the missing vehicle based on the knowledge of the generic structural characteristics of automobiles, and certain assumptions.

OLDMISS has been found to be less accurate for certain impact configurations, especially side impacts. This report examines the possible sources of errors, i.e., coding errors in the OLDMISS computer program; use of correction factors when PDOF is not perpendicular to vehicle surface; use of vehicle categories for stiffness parameters; presence of induced crush (especially in side impacts). The report investigates the relationship between the energies dissipated by the total damage and direct contact damage for side impacts.

This report also details an alternate algorithm for estimating the energy absorbed by the missing vehicle. This proposed method bypasses the need for estimating the damage profile on the missing vehicle. It also takes the presence of induced damage into account (for side impacts). The new algorithm is validated by reconstructing six vehicle-to-vehicle staged impacts. The results indicate a substantial reduction in errors in ΔV's when the proposed algorithm is used.

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TECHNICAL SUMMARY

Report Title: OLDMISS Algorithm Analysis.	October 1989

Report Author(s):
Prasad, Aloke K., and Monk, Michael W.

The OLDMISS computer program is used to estimate the ΔV's of vehicles in a collision when the damage to one of the vehicles is unknown. The program estimates the energy dissipated by the structure of the missing vehicle based on the knowledge of generic structural characteristics of the missing vehicle, and certain assumptions.

The main assumption is that a force balance must exist at the interface between the two colliding vehicles at the point of maximum deformation. If the damage to one of the vehicles is known, the maximum force exerted on that vehicle can be computed from the known structural properties associated with that vehicle. An equal and opposite force is assumed to act on the vehicle for which the damage dimensions are unknown. From this, the crush dimensions of the uninspected vehicle can be estimated. Once this is done, the ΔV can be computed from the damage algorithm of CRASH3.

OLDMISS has been found to be less accurate for certain impact configurations, especially side impacts. This report examines the possible sources of errors, i.e., coding errors in the OLDMISS computer program; use of correction factors when PDOF is not perpendicular to vehicle surface; use of vehicle categories for stiffness parameters; presence of induced crush (especially in side impacts). The report investigates the relationship between the energies dissipated by the total damage and direct contact damage for side impacts. Compartment side impacts using a movable rigid barrier are analyzed to find an empirical relationship between the two energies. A number of repeated rigid barrier to vehicle crash tests were performed on five vehicles at VRTC in 1989. Data from some tests performed earlier (1986) have also been examined.

This report also details an alternate algorithm for estimating the energy absorbed by the missing vehicle. This proposed method bypasses the need for estimating the damage profile on the missing vehicle. It also takes the presence of induced damage into account (for side impacts). The new algorithm is validated by reconstructing six vehicle-to-vehicle staged impacts. An additional configuration factor has been derived for front-to-side impacts. This configuration factor was derived by minimizing the percentage errors across the vehicle-to-vehicle side impacts considered. The results indicate a substantial reduction in errors in ΔV's when the proposed algorithm with the appropriate configuration factor is used.

1.0 Introduction and Theory

This report describes the suggested changes to the OLDMISS computer program. This program is used to estimate the ΔV's when damage to one of the vehicles is unknown. The program estimates the energy dissipated in the structure of the missing vehicle based on the knowledge of the generic structural characteristics of automobiles, and certain assumptions.

The main assumption is that a force balance must exist at the interface between the two colliding vehicles at the point of maximum deformation [1]. If the damage to one of the vehicles is known, the maximum force exerted on that vehicle can be computed from the known structural properties associated with that vehicle. An equal and opposite force is assumed to act on the vehicle for which the damage dimensions are unknown. From this, the crush dimensions of the uninspected vehicle can be estimated. Once this is done, the ΔV can be computed from the damage algorithm of CRASH3. The details of the above methodology can be found in [1].

2.0 Examination of OLDMISS Source Code

OLDMISS has been found to be less accurate in certain impact configurations (especially side impacts Ref [2]). One source of this inaccuracy was thought to be coding errors in the source code of the OLDMISS algorithm. The program was therefore examined for coding errors. This was done by performing calculations for staged crash test data, both by using the formulae (taken from Ref. [1]), and by running OLDMISS. The details of these calculations are shown in Appendix A. The staged crash tests used were 90° and 60° vehicle-to-vehicle side impacts. The intermediate values and the calculated crush profiles from the OLDMISS program matched the results from the equations. Therefore, it is concluded that the large discrepancies in the actual (measured) crushes and the OLDMISS output are not caused by any program coding errors. The OLDMISS algorithm was examined next for inherent errors in modelling of collisions and vehicle crushes.

3.0 Sources of Error in the OLDMISS Algorithm

3.1 Use of Correction Factors C_{f1} and C_{f2}

One of the possible sources of error in the OLDMISS formulation is the use of C_{f1} and C_{f2}, i.e., the "correction factors." These arise due to modelling of friction when the PDOF is not perpendicular to the vehicle surface. The need for such correction factors has been questioned [3] and its value limited in the current version of CRASH3. It should be noted that for head-on impacts, this factor tends to a value of 1 and for 90° impacts, the effect of the correction factor is minimal (as C_{f1} tends to equal C_{f2} for this configuration). OLDMISS was re-run with $C_{f1}= C_{f2}=1$ for the various crash tests and the results presented in a later section of this report (Sec 7.0, Validation of the new algorithm). Some improvement in the estimated crush is observed (Table D.1), although the errors are still significant.

3.2 Use of Vehicle Categories for Stiffness Parameters

OLDMISS uses the stiffness categories used in the present CRASH3 [4]. These categories result in the use of approximations for the values of stiffness parameters A, B, and G's. In all likelihood, the use of model-specific stiffness coefficient (or d_0 and d_1) will improve the accuracy of the algorithm. Such a list of d_0 and d_1 has been generated for front and rear impacts from the Agency's crash test data-base [5]. A similar list for side impacts has also been developed [6] and is included in Appendix B.

The effect of using model-specific values of d_0 and d_1 will be illustrated in Section 7.0 when the proposed algorithm (detailed in Sec 4.0) will be compared to the present OLDMISS.

3.3 Presence of Induced Crush

One of the major sources of error in the OLDMISS formulation is the modelling of direct and induced crushes. OLDMISS estimates crushes by applying equal and opposite forces on the two vehicles. Clearly, this method will work for crushes caused by direct contact between the vehicles. However, for certain impact modes, specially in side impacts, substantial amounts of induced crush may be present. The current (and proposed) measurement protocol calls for the measurement of total crush, i.e., both direct and induced crush. Also, total crush is used in generating the vehicle crush parameters d_0 and d_1 (Ref [5]). Therefore, the OLDMISS algorithm, which is valid for the direct crush only, results in large errors in generation of the missing crush profile, and subsequently, in the estimate of the energy absorbed by the missing vehicle.

It will be shown in the next section that the crush energy for the missing vehicle can be estimated directly, bypassing the need to generate the unknown crush profile.

4.0 Proposed Method for Estimating the Energy Absorbed

This section details an alternative formulation for estimating the energy absorbed by the missing vehicle. This method underscores the fact that the damage algorithm of CRASH requires the value of the energy absorbed by the two vehicles. This can be generated directly for the missing vehicle (as shown below), bypassing the need to estimate the crush profile, and then integrate across that profile. The proposed method therefore avoids the errors due to inaccurate correction factors, possible interpolation of the profile of the known vehicle, and errors due to lack of data about the extent of direct damage. Instead, a simple expression directly relating the energies absorbed by the known vehicle, and that by the missing vehicle is derived below:

The vehicle is modelled to behave like a linear dissipative spring with an offset (Fig. 4.1) i.e., the force per unit width of the crush is

$$F=A+(B.x) \tag{4.1}$$

This is the same model used in CRASH3 program. Also, it is assumed that vehicle 1 is available and vehicle 2 is the missing vehicle. At maximum crush, assuming force balance, one obtains

$$A_1+(B_1.x_1)=A_2+(B_2.x_2)$$

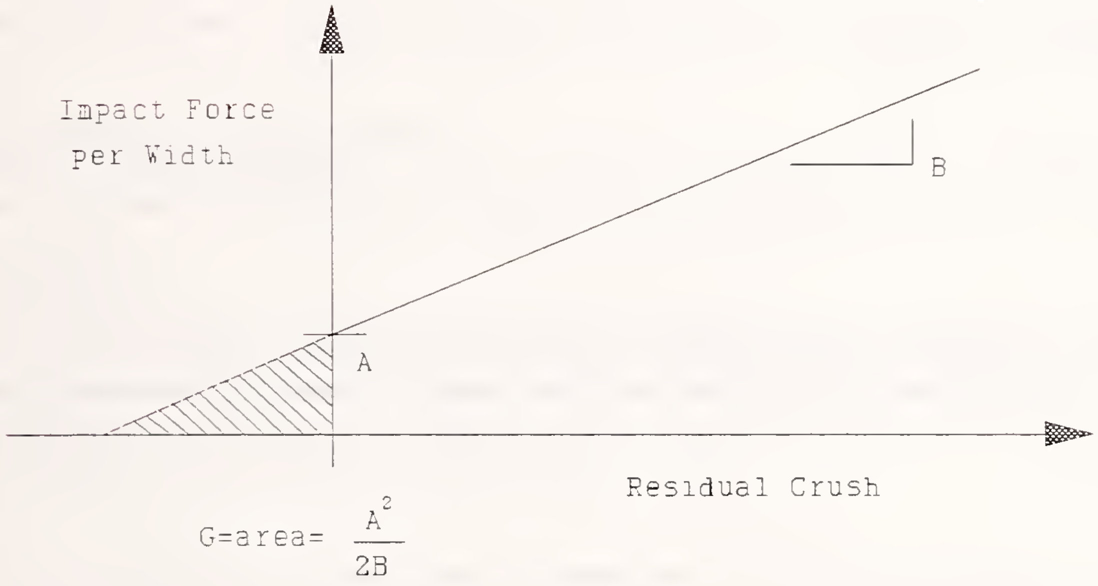

Figure 4.1 Vehicle Crush Model (A, B, and G)

where

A_1, B_1 are the stiffness coeff of veh.1
A_2, B_2 are the stiffness coeff of veh.2
x_1, x_2 are the displacements (crushes) of vehicles 1 and 2 resp.

Rearranging, one obtains

$$x_2 = \frac{A_1 - A_2 + (B_1 . x_1)}{B_2} \tag{4.2}$$

Also, from Fig.4.1, the energy absorbed per unit width of the direct crush for the vehicle 1 and missing vehicle 2 is

$$e_{D1} = \frac{B_1 . x_1^2}{2} + A_1 . x_1 + \frac{A_1^2}{2 . B_1} \tag{4.3}$$

and

$$e_{D2} = \frac{B_2 . x_2^2}{2} + A_2 . x_2 + \frac{A_2^2}{2 . B_2} \tag{4.4}$$

Substituting eq. (4.2) and (4.3) in eq. (4.4), and simplifying, provides

$$e_{D2} = \frac{B_1}{B_2} \times e_{D1} \tag{4.5}$$

The energy absorbed by the direct crush for the known vehicle 1 is obtained by integrating the quantity E_{D1} across the width of the direct crush as

$$E_{D1} = \int e_{D1} dw \tag{4.6}$$

From Eqs. (4.5) and (4.6), the energy absorbed by the direct crush on the missing vehicle is

$$E_{D2} = \int e_{D2} dw = \int \frac{B_1}{B_2} . e_{D1} dw$$

Assuming uniform stiffness along the side of the vehicle, the energy can be written as

$$E_{D2} = \frac{B_1}{B_2} . \int e_{D1} dw$$

or

$$E_{D2} = \frac{B_1}{B_2} . E_{D1} \tag{4.7}$$

It can be shown (Ref [6]) that the quantity A and B in eqn.(4.1) can be related to the intercept (d_0) and slope (d_1) of $\sqrt{\frac{2E}{W}}$ vs. crush as:

$$A=d_0 \cdot d_1 \tag{4.8}$$

$$B=d_1^2 \tag{4.9}$$

Substituting in (4.7), provides

$$E_{D2}=\frac{(d_1^2)_1}{(d_1^2)_2} \cdot E_{D1} \tag{4.10}$$

Therefore, if the energy absorbed by the direct crush of the available vehicle is known, the corresponding energy absorbed by the direct crush in the missing vehicle can be calculated by the above equation.

However, the CRASH3 damage algorithm requires the energy absorbed by the total crush (direct and induced). The relationship between the energy absorbed by the direct crush E_D and the energy absorbed by the total crush E is explored next.

5.0 Direct and Total Crush Energies

This section examines the correlation between energy absorbed by the direct crush (E_D) and that absorbed by the total (direct and induced) crush (E).

For front and rear:

OLDMISS has been shown (in Ref [2]) to be reasonably accurate for collisions involving damage to only the front or the rear of vehicles. This has also been demonstrated in the validation of the proposed algorithm in Appendix D of this report. Therefore, it is assumed that for the front and rear crushes, the total crush energy equals the direct crush energy, i.e.,

$$E=E_D \tag{5.1}$$

While this may not be true in some offset impacts, it does provide a first order estimate of the energy absorbed. The above relationship may be refined (in a manner similar to that for side impacts, as discussed below) as more offset barrier crash test results are made available.

For side:

In most impacts, substantial amounts of induced damage is present on vehicles struck on its side. Compartment side impacts using a moving rigid contoured barrier are analyzed here to find an empirical relationship between E and E_D. A number of repeated rigid barrier to vehicle crash tests were performed on five vehicles (Prelude, LeBaron, Sentra, Celebrity, and Tempo) at VRTC in 1989 (Ref [7] through [11]). Also, a number of side impact tests were performed earlier (1986) on Citation, Escort, Tredia, and LTD model vehicles (Ref [12]). Side crush coefficients d_0 and d_1 for these (and other) models were derived elsewhere (Ref [6]) and used to calculate the energy absorbed by the direct and total crush for these tests. The details are shown in Appendix C. The values of E_D are plotted against the corresponding values of E in Fig.5.1. The results clearly indicate the relation between these quantities as :

$$E=1.32E_D \tag{5.2}$$

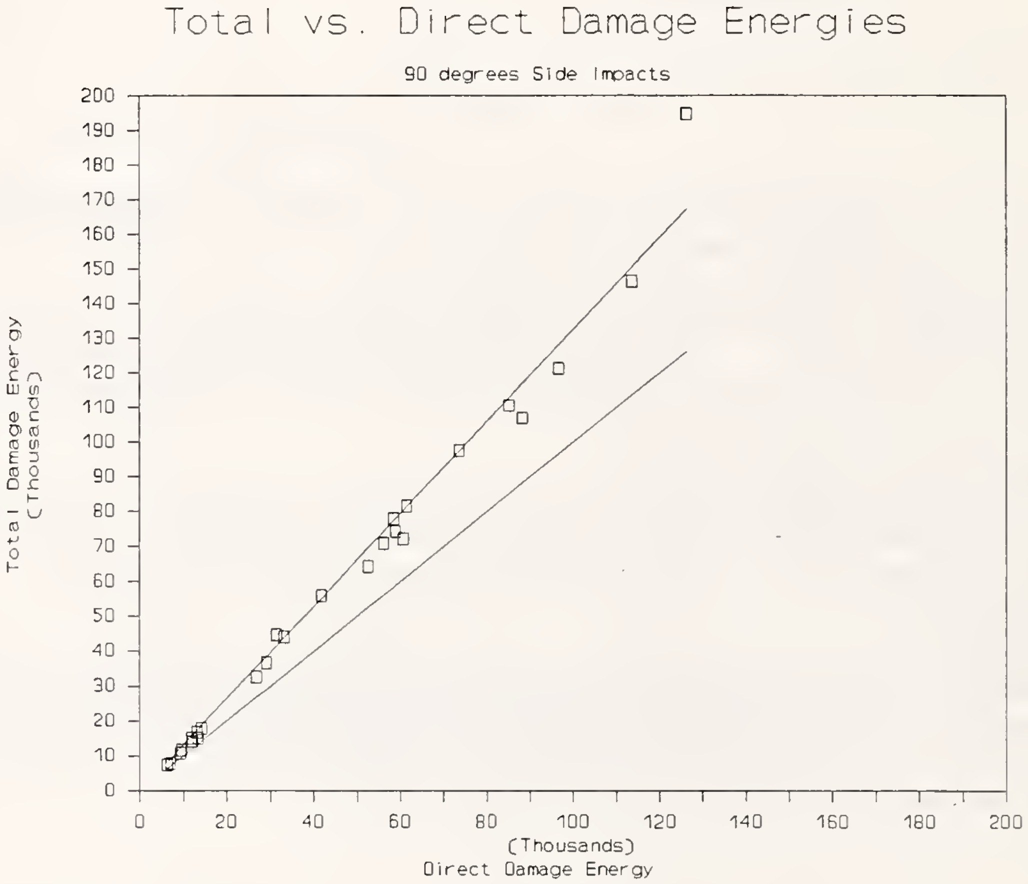

Figure 5.1 Total vs. Direct Damage Energy for Side Impacts

6.0 The Proposed Algorithm

For impacts involving only front or rear of the two vehicles, energy absorbed by the missing vehicle can be simply obtained as:

$$E_{missing}=\frac{(d_1^2)_{measured}}{(d_1^2)_{missing}}\cdot E_{measured} \tag{6.1}$$

For side impacts (involving the front/rear of one vehicle and the side of the other), two possible situations exist:

Case 1: Veh. with front/rear damage available, side damage missing:
From eqn. (5.1) and (5.2),

$$(E)_{missing}=1.32\,(E_D)_{missing}$$

and

$$(E)_{measured}=(E_D)_{measured}$$

∴ Substituting above into eq. (4.10), one obtains

$$(E)_{missing}=1.32\,\frac{(d_1^2)_{measured}}{(d_1^2)_{missing}}\cdot E_{measured} \tag{6.2}$$

Case 2: Veh. with side damage available, front/rear damage missing:
From eqn. (5.1) and (5.2),

$$(E_D)_{measured}=\frac{(E)_{measured}}{1.32}$$

and

$$(E_D)_{missing}=(E)_{missing}$$

∴ Substituting above into eq. (4.10), one obtains

$$(E)_{missing}=\frac{(d_1^2)_{measured}}{(d_1^2)_{missing}}\cdot\frac{E_{measured}}{1.32} \tag{6.3}$$

It should be noted that all crush measurements are of total damage and yield E values for the available vehicles. Also, it is assumed that d_0 and d_1 values for both measured and missing vehicles are available from Table B.1 in Appendix B, or from vehicle classification schemes developed in Ref. [6].

7.0 Validation of the Proposed Algorithm

The proposed algorithm is validated by comparing its output to that from the present version of OLDMISS. Data from a number of staged vehicle-to-vehicle impacts are examined. For each of these cases, the values of energy absorbed are calculated from the measured or estimated crush values and equations (C.1) in Appendix C. The measured crush profiles are obtained from the data-base and test reports. The crush energy coefficients d_0 and d_1 are available in Table B.1 in Appendix B for side damage, and in Ref [5] for front and rear damage. For each test, the following are calculated:

1 Energy absorbed as predicted by the CRASH3 algorithm, using vehicle specific values of d_0 and d_1. This is obtained from measured crushes and d_0 and d_1, using Eqn. (C.1). The OLDMISS model uses the CRASH3 algorithm for estimating the energies absorbed after estimating the unknown crush profile on the missing vehicle. Therefore, the value of energy absorbed, as calculated by using the actual crushes,is used as the reference for calculating the errors in the estimated energies using the various methods described below.

2 The present OLDMISS results. This is obtained by running the present OLDMISS without any changes. The energies, therefore, have been estimated using the A, B, and G coefficients according to vehicle categories in Table 1.2, in Ref [4].

3 The present OLDMISS with $C_{f1}=C_{f2}=1.0$. This will indicate the possible improvement in the results by eliminating the correction factors.

4 The present OLDMISS with $C_{f1}=C_{f2}=1.0$ and vehicle specific crush coefficients d_0 and d_1. This is the best possible estimate from the present OLDMISS algorithm.

5 The proposed algorithm. This estimates the energy of the missing vehicle using the algorithm described in Sec. 6.0 of this report.

The calculations and OLDMISS outputs for each of the tests are included in Appendix D. The errors from the various methods is summarized in Table 7.1. It can be seen that the present method (method #2 in Table 7.1) results in extremely high errors in front to side collisions. These errors are greatly reduced if the proposed algorithm (method #5 in Table 7.1) is used. However, the errors are still quite high for three of the four side collisions. A possible enhancement to the proposed algorithm to reduce these errors is discussed next.

8.0 Enhancements to the Proposed Algorithm

A close examination of the errors in E estimated by the proposed algorithm (method #5 in Table 7.1) indicates that the algorithm over-estimates the energy absorbed by the front and under-estimates the energy absorbed by the sides of vehicles in a front-side collision. One possible source of this error is the relationship between the total and direct damage energies (Eqn 5.2). That relationship was derived using certain assumptions (see Appendix C). For example, it assumes that the crush profile in vehicle-to-vehicle side impacts is similar to those produced in 90° side impact with a moving rigid barrier. It may be possible to represent this relationship more accurately by using an impact configuration factor κ for front-side impacts. Equation (5.2) would therefore become as follows:

Test	Missing Vehicle	Missing Vehicles Damaged Side	% Error† in E				
			Method of Estimating E				
			2	3	4	5	6
Calspan #1	1	Front	-26.2	-26.2	-8.4	-8.3	-8.3
	2	Front	-12.7	-12.7	9.1	9.0	9.0
Calspan #4	1	Front	224.1	214.0	-18.2	-17.2	-17.2
	2	Rear	-49.7	-48.2	29.3	20.7	20.7
Calspan #2	1	Side	-77.7	-77.7	-60.2	-47.1	-16.9
	2	Front	974.0	974.0	221.1	89.0	20.4
Calspan #3	1	Side	-86.7	-72.6	-52.2	-44.7	-13.1
	2	Front	2106.0	972.4	224.7	80.7	15.1
Test #547	2	Side	-50.0	-50.0	-50.0	-40.4	-6.5
	1	Front	73.3	73.3	126.5	67.9	6.9
Test #570	2	Side	-63.6	-63.6	-32.0	-10.1	41.2
	1	Front	422.0	422.0	66.0	11.2	-29.1
Side Impact - RMS Error			835.7	511.8	127.3	56.0	21.6
Side Impact - Average |Error|			481.7	338.2	104.1	48.9	18.7

Method of estimating E

2 Present OLDMIS
3 Present OLDMIS with $C_{f1}=C_{f2}=1.0$
4 Present OLDMIS with $C_{f1}=C_{f2}=1.0$ and vehicle-specific d_0 and d_1
5 Proposed Algorithm
6 Proposed Algorithm with Enhancement

† The error is a percentage of the 'actual' energy absorbed by the missing vehicle (calculated by integrating the measured damage profile and using vehicle-specific crush coefficients).

Table 7.1 Reconstruction Errors in E

For side:

$$E=\kappa(1.32E_D) \tag{8.1}$$

Equations (6.2) and (6.3) become

$$(E)_{missing}=(1.32\ \kappa)\ \frac{(d_1^2)_{measured}}{(d_1^2)_{missing}}\cdot E_{measured} \tag{8.2}$$

and

$$(E)_{missing}=\frac{(d_1^2)_{measured}}{(d_1^2)_{missing}}\cdot\frac{E_{measured}}{(1.32\ \kappa)} \tag{8.3}$$

respectively.The optimum value of this impact configuration factor κ was found by examining the values of the RMS error and average |errors|. The behavior of these quantities with κ is indicated in Figure 8.1. A value of (see Fig 8.1)

$$\kappa=1.57 \tag{8.4}$$

reduces the RMS error in estimated absorbed energy in the missing vehicle from 56% to a more acceptable 21.6%. It should be noted that ΔV is proportional to the square root of the energy absorbed. Therefore, the errors in ΔV will be about 10% in magnitude. It should be emphasized that the value of κ indicated above has been obtained from analyzing four vehicle-to-vehicle front-side impacts. This value of the configuration factor can be further refined as additional data becomes available. The percent errors in E using equations (8.2), (8,3) and (8.4) are included in Table 7.1 (as method #6) for comparison.

9.0 Reconstruction of RICSAC Tests

The twelve RICSAC tests are reconstructed to illustrate the improved accuracy of the proposed technique. For each of the tests, the energy absorbed (E) by the missing vehicle is computed by the present OLDMISS algorithm and by the new algorithm. These values are then compared with the value obtained by integrating the measured crush profiles (and using equation (C.1) with vehicle-specific values of crush coeff. d_0 and d_1). Note that this is the value of E as estimated by the re-formulated CRASH3 damage algorithm (as suggested in Ref. [6]).

Also, note that the comparisons are carried out with the values of energy absorbed, and not ΔV's. This is because this study evaluates different algorithms for estimating the energies absorbed by the missing vehicles. These values of energies absorbed are subsequently used to estimate ΔV's using the CRASH3 damage algorithm. However, certain other factors can have an influence on the accuracy of ΔV's (e.g., eliminating correction factor, use of vehicle-specific crush coefficients, etc.). The reformulation of the CRASH3 damage algorithm is discussed in Ref. [6]. Therefore, the issue of dealing with missing vehicles can be studied in isolation by examining the values of the estimates of the energy absorbed by the damaged vehicles. These values can then be used to

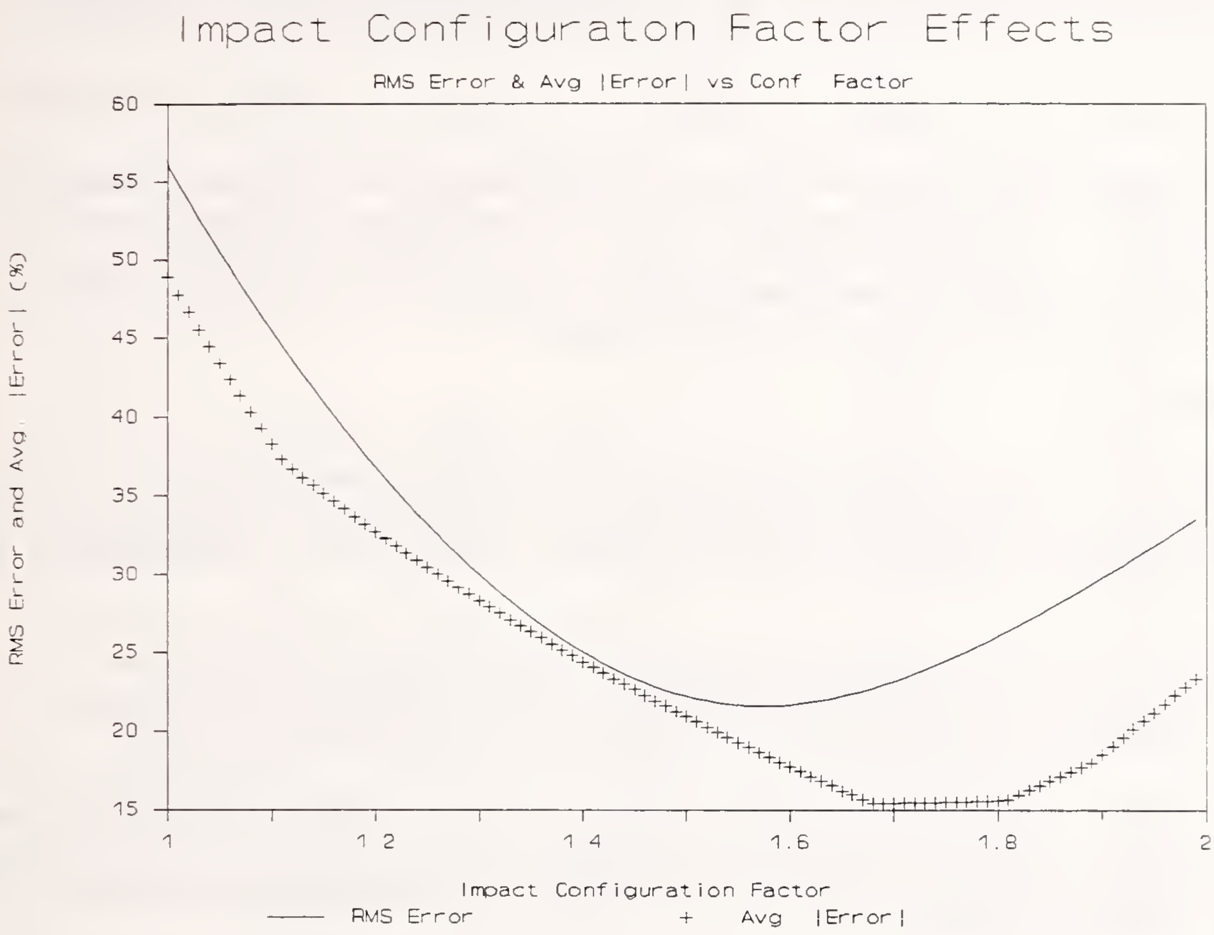

Figure 8.1 Impact Configuration Factor Effects

get the ΔV's, as described in Ref. [6]. It should be noted that the value of ΔV in CRASH3 is proportional to the square root of **E**. Therefore, the percentage errors in ΔV should be approximately half of the errors in E.

The errors in the value of energy absorbed by the missing vehicle, as predicted by the present OLDMISS and by the proposed algorithm are summarized in Table 9.1. It can be observed that the rms error is reduced substantially by using the new algorithm instead of the present OLDMISS.

It should also be noted that the new formulation (equations (8.2)-(8.4)) uses the values of d_1 (the slope of $\sqrt{\frac{2E_A}{W}}$ vs. crush). Therefore, the results are strongly influenced by the accuracy of this parameter. For most side impacts, the values of d_1 for vehicle models are calculated by assuming an intercept d_0=30 (see Ref. [6]). As more accurate values of d_1 become available, say by crash testing vehicle models at varying impact energies, the accuracy of the missing vehicle algorithm will increase accordingly.

10.0 Conclusions

- The results of the Calspan investigation of the OLDMISS model are confirmed in that it is found to be moderately accurate for front-to-front collisions, less accurate for front-to-rear collisions, and severely inaccurate for front-to-side collisions.

  One front-to-front collision resulted in 19% average energy error.
  One front-to-rear collision resulted in 137% average energy error.
  Four front-to-side collisions resulted in 836% RMS energy error.

- The revised algorithm proposed herein (with configuration enhancement) significantly reduces the percent energy error for front-to-side collisions. RMS energy error was reduced to 22%, which would result in about 10% error in delta-v computations.

- It was found unnecessary to compute an estimated damage profile for the missing vehicle. The direct contact energy absorbed by the missing vehicle was derived (subject to certain assumptions) to be a simple function of the crush properties of each vehicle multiplied by the energy absorbed by the measured vehicle.

- The primary source of error for OLDMISS was found to be the lack of means to account for induced damage in side impacted vehicles. The present OLDMISS model assumes the missing partner vehicle has only direct contact damage.

- Large errors in crushes predicted are not caused by any coding errors.

- Vehicle specific crush characteristics were noted to provide some improved accuracy in all 3 collision modes. These coefficients were computed in another recent study for all of the vehicles in the NHTSA database.

- Removal of the correction factor for oblique force directions (same as CRASH 3) was noted to provide improvement in the one oblique side impact

Test #	Impact Configuration	Missing Vehicle	% Error† in Energy Absorbed by Missing Vehicle	
			OLDMISS	New Algorithm
RICSAC # 1	Oblique Offset Side	2	- 86.4	- 37.4
		1	1816.2	59.7
RICSAC # 2	' ' ' '	2	- 93.0	- 69.5
		1	5436.0	228.2
RICSAC # 3	Oblique Offset Rear	2	- 16.9	62.0
		1	103.0	- 38.3
RICSAC # 4	' ' ' '	2	- 59.1	- 13.7
		1	246.4	15.8
RICSAC # 5	' ' ' '	2	- 90.4	- 80.8
		1	1524.6	419.8
RICSAC # 6	Oblique Offset Side	2	- 88.7	- 71.5
		1	1608.7	251.1
RICSAC # 7	' ' ' '	2	- 88.6	- 68.5
		1	1952.4	217.1
RICSAC # 8	90 Deg Offset Side	2	- 28.6	- 26.6
		1	299.6	36.3
RICSAC # 9	' ' ' '	2	299.7	207.8
		1	- 9.0	- 67.5
RICSAC #10	' ' ' '	2	238.1	172.7
		1	- 4.6	- 63.3
RICSAC #11	Oblique Offset Front	2	- 17.6	17.6
		1	- 16.6	- 15.0
RICSAC #12	' ' ' '	2	28.4	91.3
		1	- 50.6	- 47.8
		RMS Error	1321.7	139.2
		Avg|Error|	591.8	99.1

† The error is a percentage of the 'actual' energy absorbed by the missing vehicle (calculated by integrating the measured damage profile and using vehicle-specific crush coefficients).

Table 9.1 Reconstruction of RICSAC Tests

examined in this study. Overall the correction factor was not found to have much effect on energy predictions.

- Empirical coefficients were derived to correct for the lack of induced damage for front-to-side collisions.

  26 rigid-barrier-to-stationary vehicle side impacts were examined, and a factor of **1.32** found to correct direct contact damage energy to total energy. These data show a strong correlation.

  An added "configuration factor" appears to be necessary to correct for the energy present in induced damage from moving vehicle to moving vehicle collisions. This factor was found to be **1.57**, based upon the 4 side impact cases examined in this study. This should be confirmed with additional car-to-car side impacts. The product of these two factors, **2.1** is noted to minimize the errors in the side impacts examined.

- Reconstructing RICSAC tests using the new algorithm reduced the overall rms percent error of the energy absorbed by the missing vehicles to 139% from 1322% (from the present OLDMISS).

11.0 Recommendation

It is recommended that the OLDMISS model be revised to include the formulation derived in this study, in conjunction with the use of vehicle-specific values of d_0 and d_1. The "configuration factor" of 2.1 (product of 1.32 and 1.57) is recommended for the present. If further study of car-to-car side impacts reveals some alteration, this could be changed at a later time. The equations, in their final form, are reproduced below:

Impacts involving damage to only front or rear of vehicles :

$$E_{missing}=\frac{(d_1^2)_{measured}}{(d_1^2)_{missing}}\cdot E_{measured} \tag{11.1}$$

Impacts involving damage to sides and fronts of the vehicles :

Case 1: Veh. with front/rear damage available, side damage missing:

$$E_{missing}=2.1\frac{(d_1^2)_{measured}}{(d_1^2)_{missing}}\cdot E_{measured} \tag{11.2}$$

Case 2: Veh. with side damage available, front/rear damage missing:

$$E_{missing}=\frac{(d_1^2)_{measured}}{(d_1^2)_{missing}}\cdot \frac{E_{measured}}{2.1} \tag{11.3}$$

12.0 References

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[13] Warner C.Y., Allsop D.L., Germane G.J. : "A Repeated-Crash Test Technique for Assessment of Structural Impact Behavior", SAE 860208, 1986.

Appendix A
Verification of OLDMISS Source-code

A.1 Introduction

The source code of the present version of OLDMISS is examined for errors by comparing the program output of the estimated damage on the missing vehicle with results obtained from hand calculations using equations in Ref. [1]. Results from two vehicle-to-vehicle staged side impacts are used to compare the OLDMISS, hand calculations, and measured crushes on the missing vehicles. The crash test results and OLDMISS input/output files can be found in Ref. [2] and section A.5 of this Appendix.

A.2 A 90° Side impact

A 90° side impact between two 1982 Chevrolet Citations is considered. The Vehicle #1 was travelling at 17.08 mph and was struck on the left side by Vehicle #2 travelling at velocity of 34.16 mph. The measured crushes are listed in Table A.1.

OLDMISS results:

Veh. #2 was assumed to be available and Veh. #1 missing. The output from OLDMISS for the estimated damage on Veh. #1 side are:

L = 61.0 in.
C_1 = 3.8 in.
C_2 = 3.8 in.
C_3 = 4.2 in.
C_4 = 4.2 in.
C_5 = 4.4 in.
C_6 = 5.0 in.

Hand Calculations

From Ref. [1], we have the equation for the missing vehicle crushes as

$$\delta_1=\left\{\left(\frac{C_{f2}}{C_{f1}}\cdot\frac{A_2}{B_1}\cdot\frac{L_2}{L_1}\right)-\frac{A_1}{B_1}\right\}+\left(\frac{C_{f2}}{C_{f1}}\cdot\frac{B_2}{B_1}\cdot\frac{L_2}{L_1}\right)\cdot\delta_2 \qquad \text{(A.1)}$$

where

$$C_{f1}=C_{f2}=\frac{1}{\cos\alpha}$$

and

α = 26.6° (see Fig. A.1)
A_1 = 173.3 ($\mathrm{lb_f/in}$)
B_1 = 57.1 ($\mathrm{lb_f/in^2}$)
A_2 = 373 ($\mathrm{lb_f/in}$)
B_2 = 38 ($\mathrm{lb_f/in^2}$)

The above values have been taken from Table 1.2 in Ref. [4]. Also,

L_1 = L_2 = 61 in. Ref [1]

Using above values, we get

$\delta_1 = 3.50877 + 0.66667 \cdot \delta_2$

Using above, we get the crushes on the missing vehicle (the order is reversed due to the numbering scheme for the six crush value on the front and side). They are:

L = 61.0 in.
C_1 = 3.8 in.
C_2 = 3.8 in.
C_3 = 4.2 in.
C_4 = 4.2 in.
C_5 = 4.4 in.
C_6 = 5.0 in.

These values match the OLDMISS output. For comparison purposes, the OLDMISS estimates and experimental measured values of the crushes on the missing vehicle are summarized in Table A.1.

A.3 A 60° Side Impact

A 60° side impact between two 1982 Chevrolet Citations is considered. The Vehicle #1 was travelling at 12.99 mph and was struck on the left side by Vehicle #2 travelling at velocity of 25.98 mph. The measured crushes are listed in Table A.1.

OLDMISS results:

Veh. #2 was assumed to be available and Veh. #1 missing. The output from OLDMISS for the estimated damage on Veh. #1 side are:

L = 53.3 in.
C_1 = 2.2 in.
C_2 = 2.2 in.
C_3 = 2.4 in.
C_4 = 2.7 in.
C_5 = 2.9 in.
C_6 = 2.7 in.

Hand Calculations

From Ref. [1], we have the equation for the missing vehicle crushes as

$$\delta_1 = \left\{ \left(\frac{C_{f2}}{C_{f1}} \cdot \frac{A_2}{B_1} \cdot \frac{L_2}{L_1} \right) - \frac{A_1}{B_1} \right\} + \left(\frac{C_{f2}}{C_{f1}} \cdot \frac{B_2}{B_1} \cdot \frac{L_2}{L_1} \right) \cdot \delta_2$$

where (see fig. A.2)

C_{f1} = $1/\cos \alpha_1$ = $1/\cos 49°$ = 1.5242
C_{f2} = $1/\cos \alpha_2$ = $1/\cos 19°$ = 1.0576

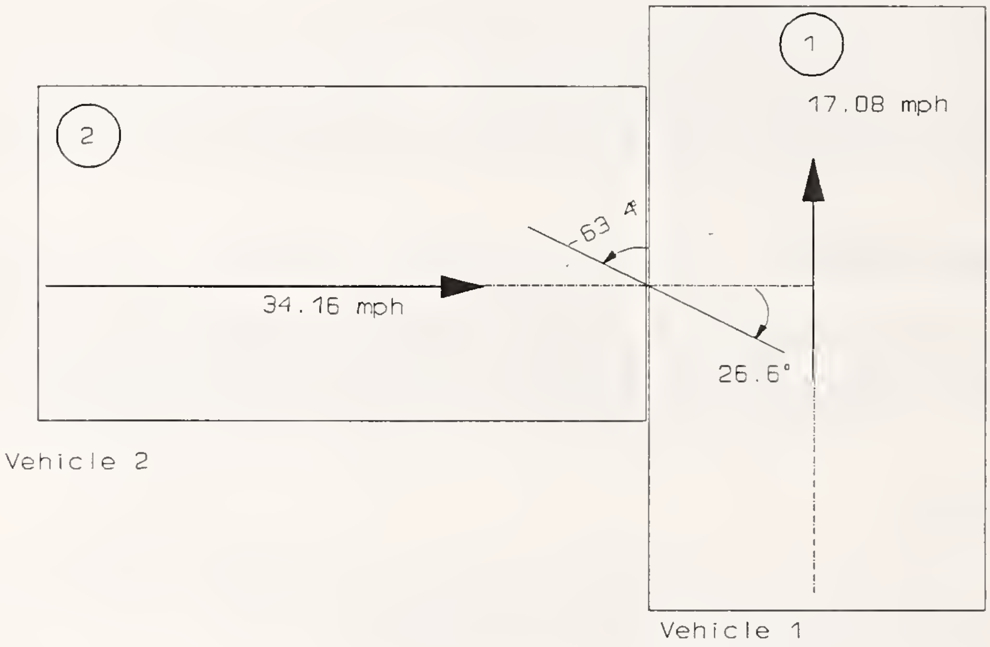

Figure A.1 Impact Geometry, 90 deg Impact

$A_1 = 173.3\ (lb_f/in)$
$B_1 = 57.1\ (lb_f/in^2)$
$A_2 = 373\ (lb_f/in)$
$B_2 = 38\ (lb_f/in^2)$

The above values have been taken from Table 1.2 in Ref. [4]. Also, from Ref [1],

$$L_1 = L_2 . \cos\gamma + \delta_{2max} . |\sin\gamma| \\ = 53.3 \textit{ inches.}$$

as

$\gamma = 30°$ (see fig. A.2)

Using above values, we get

$$\delta_1 = 2.15846 + 0.5291 \times \delta_2$$

Using above, we get the crushes on the missing vehicle (the order is reversed due to the numbering scheme for the six crush value on the front and side). They are:

$L = 53.38$ in.
$C_1 = 2.2$ in.
$C_2 = 2.2$ in.
$C_3 = 2.4$ in.
$C_4 = 2.7$ in.
$C_5 = 2.9$ in.
$C_6 = 2.7$ in.

These values match the OLDMISS output. For comparison purposes, the OLDMISS estimates and experimental measured values of the crushes on the missing vehicle are summarized in Table A.1.

A.4 Conclusions

From the above calculations, we conclude that the large discrepancies in the predicted crush values (Table A.1) from OLDMISS are not caused by coding errors. They are inherent in the model and its simplifying assumptions.

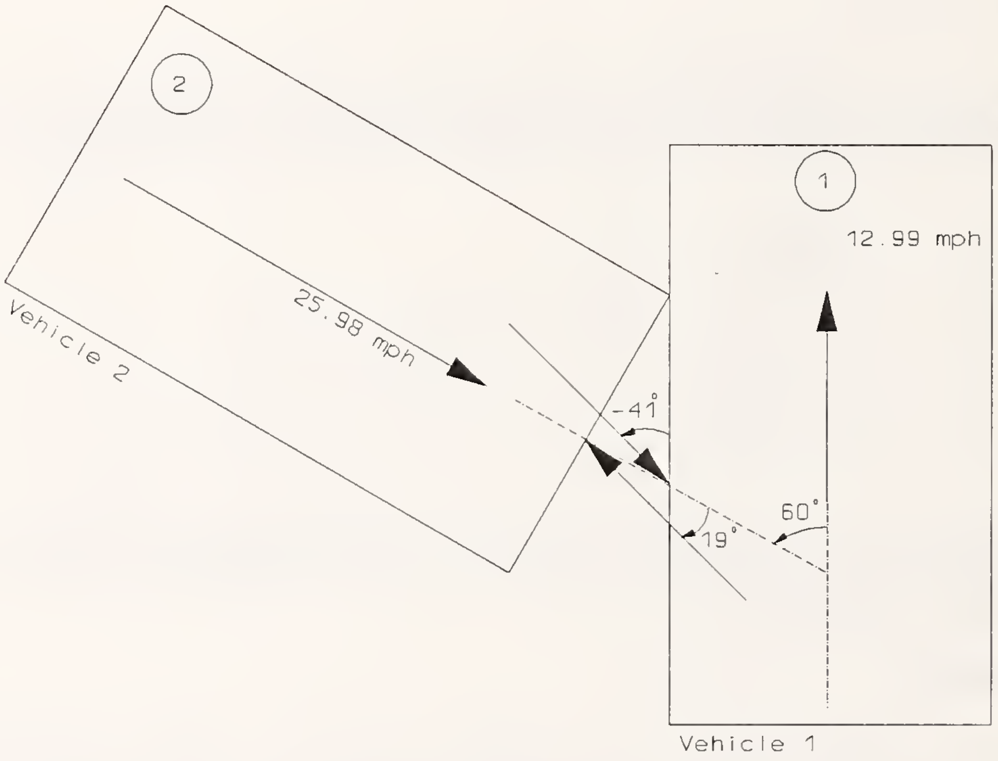

Figure A.2 Impact Geometry, 60 deg Impact

Test	Missing Vehicle	Damaged Side	Measured Crushes (in.)							OLDMISS Output and Hand Calculations						
			L	C1	C2	C3	C4	C5	C6	L	C1	C2	C3	C4	C5	C6
90 deg	1	Side	86.0	1.8	16.3	13.5	13.0	11.5	0.5	61.0	3.8	3.8	4.2	4.2	4.4	5.0
	2	Front	61.0	2.3	1.3	1.0	1.0	0.5	0.5	76.2	11.7	17.7	19.1	21.2	20.6	0.0
60 deg	1	Side	84.0	0.0	6.5	13.5	15.6	13.5	0.2	61.0	1.0	1.4	1.0	0.5	0.1	0.0
	2	Front	53.3	2.2	2.2	2.4	2.7	2.9	2.7	67.7	0.0	12.3	27.1	36.8	39.1	34.6

Table A.1 Measured and Predicted Crushes

A.5 OLDMISS Input and Output Files

A.5.1 Input file for 90 degree side impact

```
Calspan Test #2; Test #546; 90 deg impact; veh 2 known
    3    3    3    9    6    2    1
 3210.00 3000.00     .00   90.00
L F
   61.00     .00     .00   26.60
    2.30    1.30    1.00    1.00     .50     .50
```

A.5.2 Output file for 90 degree side impact

```
1




       SUMMARY OF OLDMISPC RESULTS

 Calspan Test #2; Test #546; 90 deg impact; veh 2 known

                                     SPEED CHANGE (DAMAGE)

                       RESULTANT        LONGITUDINAL       LATERAL         PDOF
                       MPH   (KPH)      MPH    (KPH)     MPH    (KPH)      DEG

 VEH #1 (ESTIMATED)   10.12 ( 16.29)    -4.53 ( -7.29)    9.05 ( 14.56)   -63.40
 VEH #2 (KNOWN)       10.83 ( 17.43)    -9.68 (-15.58)   -4.85 ( -7.80)    26.60


                              ENERGY                         FORCE
                         FT-LBS     (NT-M)                LBS      (NT)

 VEH #1 (ESTIMATED)      9490.8   ( 12866.6)            28141.2  (125172.3)
 VEH #2 (KNOWN)         14261.2   ( 19333.7)            28141.2  (125172.3)
1
                           SUMMARY OF DAMAGE DATA

             VEHICLE #1                            VEHICLE #2
    (ESTIMATED DAMAGE DIMENSION)           (KNOWN DAMAGE DIMENSION)
                  IN       (CM)                           IN      (CM)

 L-----------     61.0    154.9          L-----------     61.0    154.9
 C1----------      3.8      9.7          C1----------      2.3      5.8
 C2----------      3.8      9.7          C2----------      1.3      3.3
 C3----------      4.2     10.6          C3----------      1.0      2.5
 C4----------      4.2     10.6          C4----------      1.0      2.5
 C5----------      4.4     11.1          C5----------       .5      1.3
 C6----------      5.0     12.8          C6----------       .5      1.3
 D-----------       .0       .0          D-----------       .0       .0

                                VEHICLE INFORMATION

                VEHICLE #1                            VEHICLE #2
          (SIDE DAMAGE UNKNOWN)                 (FRONT DAMAGE KNOWN)


 SIZE------       3                       SIZE------       3
 STIFFNESS-       3                       STIFFNESS-       9
 SIDE------       L                       SIDE------       F
 HANGL-----      .0 DEG                   HANGL-----    90.0 DEG
 WEIGHT----  3210.0 LBS (1455.8 KG)       WEIGHT----  3000.0 LBS (1360.5 KG)
 MASS------     8.307 LB-SEC**2/IN        MASS------     7.764 LB-SEC**2/IN
            (  93.86 NT-SEC**2/CM)                   (  87.72 NT-SEC**2/CM)
 RADIUS                                   RADIUS
 GYRATION--  3324.0 IN**2                 GYRATION--  3324.0 IN**2
          ( 21445.1 CM**2)                         ( 21445.1 CM**2)
```

A.5.3 Input file for 60 degree side impact

```
Calspan Test #3; Test #582; 60 deg impact; veh 2 known
    3    3    3    9    6    2    1
 3140.00 3000.00     .00  120.00
L F
   61.00     .00     .00   19.00
    1.00    1.40    1.00     .50     .10     .00
```

A.5.4 Output file for 60 degree side impact

```
1





      SUMMARY OF OLDMISPC RESULTS

 Calspan Test #3; Test #582; 60 deg impact; veh 2 known

                                              SPEED CHANGE (DAMAGE)

                               RESULTANT        LONGITUDINAL        LATERAL          PDOF
                               MPH   (KPH)      MPH    (KPH)      MPH    (KPH)       DEG

 VEH #1 (ESTIMATED)            9.05 ( 14.56)   -6.83 (-10.98)    5.94 (  9.55)    -41.00
 VEH #2 (KNOWN)                9.47 ( 15.24)   -8.95 (-14.41)   -3.08 ( -4.96)     19.00


                                     ENERGY                            FORCE
                                FT-LBS    (NT-M)                    LBS       (NT)

 VEH #1 (ESTIMATED)              7847.0   ( 10638.1)              25779.6   (114667.6)
 VEH #2 (KNOWN)                 11970.9   ( 16228.8)              25779.6   (114667.6)
1
                                  SUMMARY OF DAMAGE DATA

                    VEHICLE #1                            VEHICLE #2
            (ESTIMATED DAMAGE DIMENSION)           (KNOWN DAMAGE DIMENSION)
                           IN       (CM)                          IN       (CM)

 L-----------     53.3     135.5          L-----------     61.0     154.9
 C1----------      2.2       5.5          C1----------      1.0       2.5
 C2----------      2.2       5.6          C2----------      1.4       3.6
 C3----------      2.4       6.1          C3----------      1.0       2.5
 C4----------      2.7       6.8          C4----------       .5       1.3
 C5----------      2.9       7.3          C5----------       .1        .3
 C6----------      2.7       6.8          C6----------       .0        .0
 D-----------       .0        .0          D-----------       .0        .0

                                     VEHICLE INFORMATION

                       VEHICLE #1                              VEHICLE #2
                 (SIDE DAMAGE UNKNOWN)                    (FRONT DAMAGE KNOWN)


 SIZE------        3                      SIZE------        3
 STIFFNESS-        3                      STIFFNESS-        9
 SIDE------        L                      SIDE------        F
 HANGL-----       .0 DEG                  HANGL-----    120.0 DEG
 WEIGHT----   3140.0 LBS (1424.0 KG)      WEIGHT----   3000.0 LBS (1360.5 KG)
 MASS------       8.126 LB-SEC**2/IN      MASS------       7.764 LB-SEC**2/IN
             (  91.81 NT-SEC**2/CM)                   (  87.72 NT-SEC**2/CM)
 RADIUS                                   RADIUS
 GYRATION--   3324.0 IN**2                GYRATION--   3324.0 IN**2
          ( 21445.1 CM**2)                         ( 21445.1 CM**2)
```

Appendix B
Vehicle Crush Parameters in Side Impact

Vehicle crush parameters d_0 and d_1 for sides have been calculated from crash test data in the Agency's data-base and are presented in Table B.1. The details can be found in Ref [6]. Also, d_0 and d_1 for front and rear impacts have been listed in Ref [5]. Classification schemes for estimating these parameters for vehicle models not tested by the Agency are being developed.

Test#	Yr	Make	Model	Bdy	Barrwt	Weight	WhlBas	Barrvel	d0	d1	Remarks
***	82	VOLKSWAGEN	RABBIT	3H	3006	2447	95.5	28.6	30.0	6.881	From Tests 512, 513
***	82	CHEVROLET	CITATION	5H	3017	3069	104.8	39.3	30.0	7.786	From Tests 548, 549
***	82	VOLKSWAGEN	RABBIT	2S	2990	2546	94.0	29.1	30.0	8.350	From Tests 603, 604
***	81	CHEVROLET	CITATION	5H	2990	3045	104.8	33.5	30.0	7.482	From Tests 675, 676
677	82	CHEVROLET	CITATION	3H	2990	3100	104.9	33.5	30.0	6.494	
678	81	PLYMOUTH	HORIZON	5H	2990	2600	99.1	33.5	30.0	7.688	
679	81	DODGE	OMNI	3H	2990	2680	96.8	33.5	30.0	6.983	
683	81	FORD	GRANADA	2S	2990	3380	105.4	33.5	30.0	6.641	
684	81	FORD	GRANADA	4S	2990	3415	105.6	33.5	30.0	6.023	
702	80	AMERICAN	CONCORD	SW	2990	3555	108.5	33.5	30.0	7.195	
***	82	NISSAN/DATSUN	SENTRA	2S	2990	2340	94.6	33.5	30.0	5.945	From Tests 704, 820
710	81	VOLKSWAGEN	RABBIT	2S	2990	2403	94.9	33.5	30.0	6.750	
***	82	HONDA	CIVIC	4S	2990	2488	91.3	33.4	30.0	7.407	From Tests 719, 863
744	82	DODGE	400	2C	2990	3028	100.0	33.5	30.0	5.337	
748	81	VOLKSWAGEN	RABBIT	3H	2990	2520	95.5	39.3	30.0	7.591	
811	81	HONDA	CIVIC	4S	2982	2468	91.3	33.5	30.0	7.286	
855	83	MAZDA	626	4S	2984	2827	99.5	33.4	30.0	5.504	
856	83	NISSAN/DATSUN	SENTRA	2S	2991	2382	94.5	33.4	30.0	6.454	
879	85	CHEVROLET	SPECTRUM	3H	3006	2365	94.0	33.6	30.0	7.928	
887	84	CHEVROLET	CELEBRITY	4S	2997	3374	104.9	33.6	30.0	8.260	
***	83	FORD	ESCORT	3H	3229	1985	94.3	16.1	30.0	5.449	From Tests 960,961
***	83	MITSUBISHI	TREDIA	4S	3237	2161	96.3	16.7	30.0	4.597	From Tests 962, 963
***	80	CHEVROLET	CITATION	5H	3229	2784	104.8	18.5	30.0	5.845	From Tests 964, 965
***	80	FORD	LTD	4S	3237	3554	114.3	20.9	30.0	7.928	From Tests 968, 969
1119	85	CHEVROLET	CELEBRITY	4S	2995	2849	104.8	33.1	30.0	7.235	
1145	87	NISSAN/DATSUN	SENTRA	2S	3010	2510	95.5	33.5	30.0	6.161	
1210	88	TOYOTA	TERCEL	5H	3010	2550	93.4	33.7	30.0	9.917	
1222	87	CHEVROLET	CAVALIER	4S	3010	2940	101.3	33.8	30.0	7.987	
1253	88	FORD	PICKUP	PU	3980	4103	133.0	33.4	30.0	5.806	
****	88	NISSAN/DATSUN	PICKUP	PU	3980	3283	104.4	33.2	30.0	8.434	From Tests 1254, 1270
1256	88	PONTIAC	BONNEVILLE	4S	2910	3820	111.0	33.9	30.0	7.085	
1257	88	FORD	TAURUS	4S	2910	3690	105.6	33.4	30.0	8.875	
1263	88	CHEVROLET	SPRINT	3H	2910	2100	88.5	33.7	30.0	6.985	
1264	88	HYUNDAI	EXCEL GLS	4S	2910	2700	93.6	33.9	30.0	6.481	
1268	84	FORD	RANGER	PU	3980	3038	107.0	32.9	30.0	5.151	
1269	88	CHEVROLET	CAPRICE	4S	2910	4030	115.0	33.5	30.0	9.199	
1271	88	CHEVROLET	S10 PICKUP	PU	3980	3169	108.0	33.4	30.0	8.564	
1272	88	VOLKSWAGEN	GOLF	3H	2900	2660	97.6	33.8	30.0	7.958	
1281	88	DODGE	CARAVAN	VN	3980	5024	111.8	33.6	30.0	6.798	

Table B.1 Side Crush Coefficients d_0 and d_1

Appendix C
Total and Direct Crush Energies

C.1 Introduction

The correlation between the energy absorbed by the direct damage and that absorbed by total (direct and induced) damage has been derived in the following sections. Data from 26 crash tests was studied and the above values calculated for each of the tests. All the crash tests considered were 90° moving rigid barrier impacts onto the passenger compartments of stationary vehicles. The Prelude, LeBaron, Sentra, Celebrity and Tempo were impacted using the repeated test technique (Ref.[13] and [7] through [11]), while the Citation, Escort, LTD, and Tredia were each impacted twice (once each on the opposite sides of the vehicle) (Ref.[12]).

C.2 Theory and Assumptions

The 90° side impact with the rigid moving barrier resulted in a crush pattern of the type shown in Fig. C.1. The direct crush zone was assumed to be of the same width as the rigid barrier (62.5 in.) and located in the center of the total crush zone (Fig. C.1). It should be noted that only the total crush width and the six crush measurements C_1 .. C_6 across the total crush zone are available from the damage information in the Agency's data-base. In some of the test reports, crushes at 6 inch intervals along the side have been recorded. The six crush measurements C_1 .. C_6 have been estimated from this data by linear interpolation. The damage at the six equidistant locations along the direct crush was also calculated by linear interpolation between the surrounding total crush measurements. This process is illustrated in Fig. C.1. The vehicle models, the side crush energy parameters d_0 and d_1, the measured total damage, and the calculated direct damage are listed in columns 1 through 17 of Table C.1.

Once the damage width W and six measurements C_1 .. C_6, and coeff. d_0 and d_1 are available (for either total or for direct damage), the corresponding energy absorbed can be obtained from the equations below (Ref [5])

$$E=K_1 d_0^2+K_2 d_0 d_1+k_3 d_1^2 \tag{C.1}$$

where

$$K_1=\frac{W}{2}$$

$$K_2=\frac{W}{10}\cdot\{C_1+2\times(C_2+C_3+C_4+C_5)+C_6\}$$

$$K_3=\frac{W}{30}\cdot\{C_1^2+2\times(C_2^2+C_3^2+C_4^2+C_5^2)+C_6^2+C_1C_2+C_2C_3+C_3C_4+C_4C_5+C_5C_6\}$$

These values are listed in columns 18 and 19 of Table C.1. Finally, these energy values are plotted as total energy vs. direct energy in Fig. C.2. The results indicate a strong correlation between these values. A linear regression results in the following :

$$E=1.32\times E_D \tag{C.2}$$

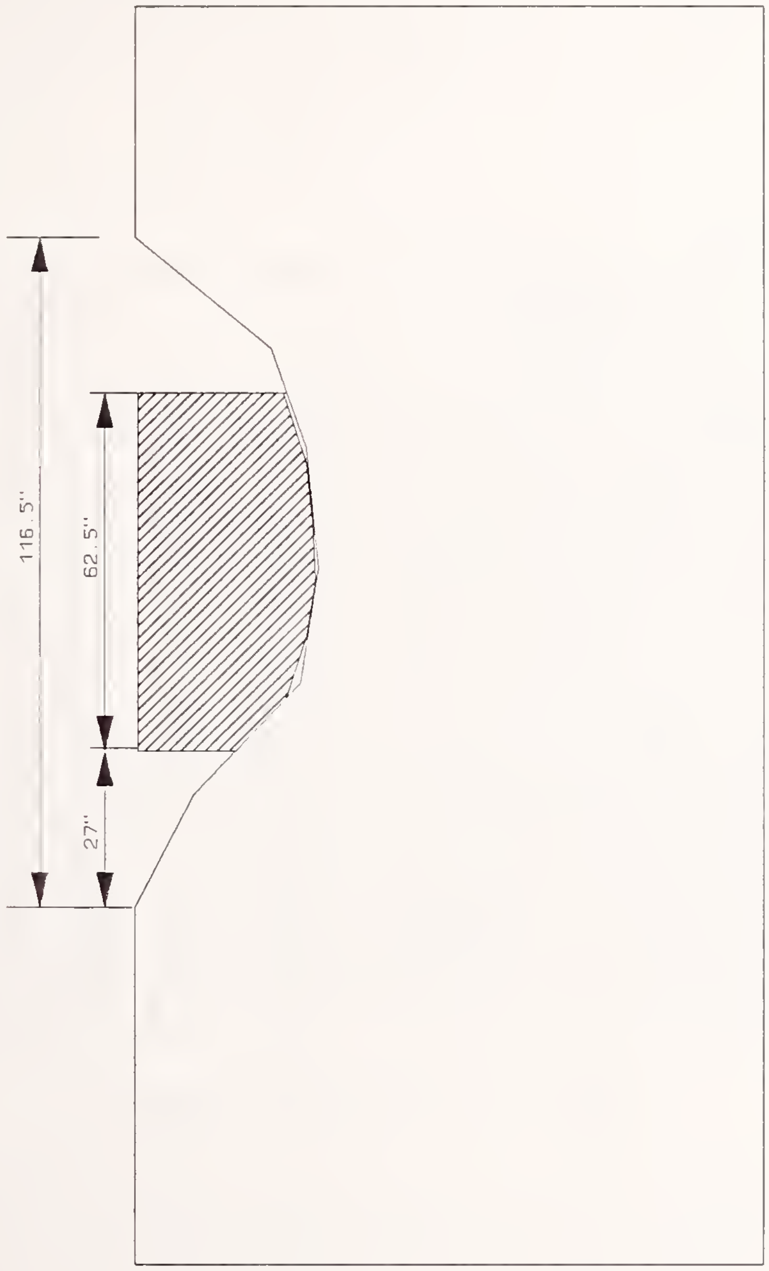

Figure C.1 Total and Direct Damage Pattern

Model	d0 (lbf)	d1 (lbf/in)	Total Crush L	C1	C2	C3 inches	C4	C5	C6	Direct Crush L	C1	C2	C3 inches	C4	C5	C6	Energy Total (ft-lbf)	Direct
Prelude	21.90	6.33	87.9	0.0	7.8	8.4	8.2	5.5	0.0	62.5	5.6	8.1	8.4	8.2	6.7	4.0	14045.1	12084.[illegible]
Prelude	21.90	6.33	112.6	0.0	8.5	14.4	15.4	10.2	0.0	62.5	9.2	12.4	14.6	15.2	13.7	10.8	36666.0	29134.[illegible]
Prelude	21.90	6.33	116.5	0.9	17.1	21.9	23.0	8.1	0.9	62.5	17.9	20.4	22.1	22.7	18.5	10.5	70905.2	56260.6
Prelude	21.90	6.33	121.3	0.7	23.8	30.3	31.3	6.4	0.7	62.5	25.2	28.5	30.5	31.1	24.5	11.7	121368.5	96682.7
LeBaron	25.30	6.96	98.2	0.0	6.4	6.8	7.9	8.1	0.0	62.5	5.8	6.6	7.0	7.7	8.0	7.4	15038.9	11844.5
LeBaron	25.30	6.96	123.8	0.2	13.5	15.1	16.8	5.0	0.2	62.5	13.9	14.7	15.5	16.4	13.8	7.8	44180.0	33058.2
LeBaron	25.30	6.96	131.4	0.8	9.2	22.0	24.2	10.4	0.8	62.5	13.2	19.3	22.6	23.6	21.3	14.7	74349.9	58885.0
LeBaron	25.30	6.96	140.8	0.0	7.8	32.0	33.8	19.8	0.0	62.5	17.2	28.0	32.5	33.3	31.5	25.3	146441.1	113600.0
Sentra	28.34	5.22	92.4	0.0	4.3	6.9	6.7	6.7	0.0	62.5	3.5	5.6	6.9	6.7	6.7	5.4	11535.6	9534.5
Sentra	28.34	5.22	127.0	0.0	5.9	14.2	15.5	15.0	0.0	62.5	8.1	12.2	14.5	15.2	15.4	15.1	44749.9	31426.8
Sentra	28.34	5.22	139.5	0.0	4.6	22.5	22.4	15.5	0.0	62.5	11.4	19.4	22.5	22.4	21.2	18.1	77878.7	58435.0
Celebrity	20.71	7.03	101.4	0.0	7.6	8.1	8.1	6.9	0.0	62.5	7.3	7.9	8.1	8.1	7.6	6.6	16607.7	13059.8
Celebrity	20.71	7.03	107.0	1.4	15.4	16.2	16.2	19.0	1.4	62.5	15.4	15.9	16.2	16.2	17.3	18.9	56058.6	41771.1
Celebrity	20.71	7.03	110.6	3.3	23.6	22.7	21.5	11.4	3.3	62.5	23.5	23.0	22.4	21.8	18.0	12.3	81472.2	61426.7
Tempo	25.23	5.10	102.0	0.0	8.2	9.2	8.5	6.0	0.0	62.5	7.9	8.8	9.1	8.6	7.5	5.8	17766.8	14156.0
Tempo	25.23	5.10	113.0	1.4	23.4	24.6	23.9	17.4	1.4	62.5	23.5	24.2	24.5	24.1	21.8	18.2	97419.1	73617.7
Tempo	25.23	5.10	139.0	0.0	25.3	33.9	30.8	29.0	0.0	62.5	28.5	32.4	33.1	31.7	30.5	29.7	194702.9	126323.4
Citation	24.30	6.87	86.0	1.8	16.3	13.5	13.0	11.5	0.5	61.0	11.7	15.1	13.4	13.1	12.1	8.0	32625.3	26857.3
Citation	24.30	6.87	78.0	0.0	9.1	8.6	8.7	8.3	0.0	62.5	4.5	8.9	8.6	8.7	8.4	4.1	14984.2	13354.6
Citation	24.30	6.87	97.0	7.0	10.7	29.9	28.6	28.1	7.0	62.5	10.3	20.9	29.7	28.8	28.4	25.8	107007.1	88330.9
Escort	24.30	6.23	75.0	0.0	5.3	5.2	5.6	5.2	0.0	62.5	2.2	5.3	5.2	5.6	5.3	2.2	7794.3	7074.8
Escort	24.30	6.23	88.5	6.0	19.1	19.1	20.0	20.8	6.0	62.5	15.6	19.1	19.2	19.9	20.4	16.9	64362.4	52562.9
LTD	24.30	8.57	85.3	0.0	6.7	6.0	6.2	6.1	0.0	62.5	4.5	6.4	6.0	6.1	6.1	6.0	10687.7	9283.1
LTD	24.30	8.57	103.0	6.4	24.9	26.1	25.6	23.1	6.4	62.5	24.6	25.6	26.0	25.7	24.6	22.8	110602.5	85184.3
Tredia	24.30	5.44	80.0	0.0	4.2	4.2	5.0	5.5	0.0	62.5	2.3	4.2	4.3	4.9	5.3	3.0	7287.0	6284.1
Tredia	24.30	5.44	88.0	2.9	24.9	22.1	20.5	19.3	2.9	62.5	18.8	23.7	21.9	20.7	19.8	14.8	72264.3	60664.8

Table C.1 Side Crush Profiles

The lower line in this graph corresponds to both these energies being equal and is shown for reference.

It should again be noted that these results have been derived from 90° compartmental impacts with rigid barriers. For side collisions in which both vehicles are in motion, the parameter value may differ from 1.32. A correction factor κ can be derived (as discussed in section 8.0 of this report) to correct for different impact conditions.

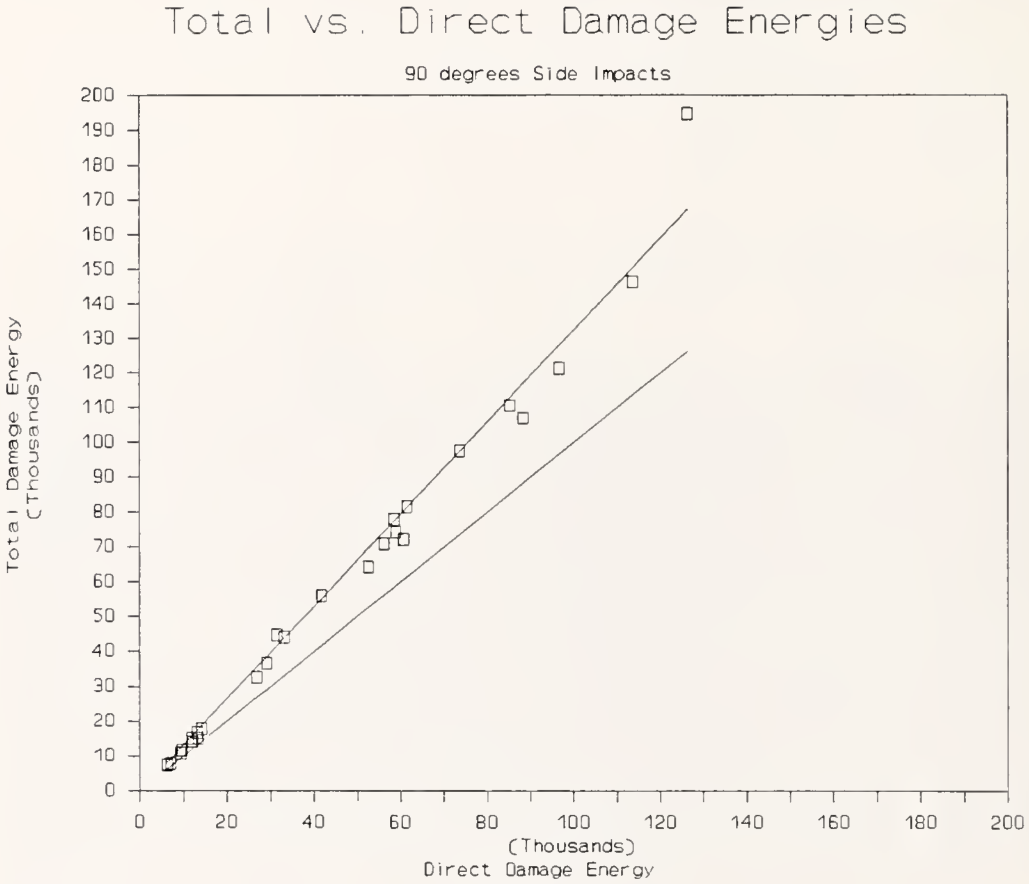

Figure C.2 Total vs. Direct Damage Energy for Side Impacts

Appendix D
Validation of the New Algorithm

Six staged vehicle-to-vehicle impacts are reconstructed using the methods described in Sec 7.0. The results are summarized in Table D.1. The tests are described in detail below.

Calspan Test #1 Front Offset Impact Ref [2]

Test description

This test involves a head-on car-to-car impact of a 1980 Chevrolet Impala (4070 lbs.) and a 1980 Chevrolet Citation (3050 lbs.) At impact, each vehicle was travelling at 30.5 mph. The measured crushes and crush coeff. are :

Vehicle #1 '80 Impala (front impact):
Vehicle specific $d_0 = 49.82\ (\sqrt{lb_f})$; $d_1 = 7.24\ (\sqrt{lb_f}/in)$ Ref [5]
Used in OLDMISS $A = 355.9\ (lf_f/in)$; $B = 33.8\ (lb_f/in^2)$ Ref [4]
Measured crushes
L = 71.0 in.
C_1 = 22.0 in.
C_2 = 24.0 in.
C_3 = 25.7 in.
C_4 = 26.9 in.
C_5 = 27.1 in.
C_6 = 27.5 in.

Vehicle #2 '80 Citation (front impact):
Vehicle specific $d_0 = 47.57\ (\sqrt{lb_f})$; $d_1 = 7.69\ (\sqrt{lb_f}/in)$ Ref [5]
Used in OLDMISS $A = 373.0\ (lf_f/in)$; $B = 38.0\ (lb_f/in^2)$ Ref [4]
Measured crushes
L = 61.0 in.
C_1 = 16.9 in.
C_2 = 20.5 in.
C_3 = 24.5 in.
C_4 = 26.1 in.
C_5 = 25.6 in.
C_6 = 25.2 in.

1. Actual crush-energy absorbed by the two vehicles is calculated using equations (C.1) and vehicle specific values of d_0 and d_1 and actual measured crushes listed above. These are the values which would be generated by the CRASH3 program, if both vehicles are available for measurement. The values are:

   E_1 = 164923.45 $(ft\text{-}lb_f)$
   E_2 = 134077.29 $(ft\text{-}lb_f)$

2. The present OLDMISS results are obtained by running OLDMISS to obtain the predicted crushes and then using equations (C.1) and the A and B values (converted to d_0 and d_1) used in OLDMISS. The predicted crushes and calculated energies absorbed for the two possible cases are:

   Vehicle #1 missing, Vehicle #2 available
   L = 61.0 in.
   C_1 = 28.8 in.
   C_2 = 29.3 in.
   C_3 = 29.8 in.
   C_4 = 28.1 in.
   C_5 = 23.6 in.
   C_6 = 19.5 in.
   E_{1est2} = 121775.1 $(ft\text{-}lb_f)$
   %Error= -26.2 %

Vehicle #2 missing, Vehicle #1 available
L = 71.0 in.
C_1 = 24.0 in.
C_2 = 23.7 in.
C_3 = 23.5 in.
C_4 = 22.4 in.
C_5 = 20.9 in.
C_6 = 19.1 in.
E_{2est2} = 116986.3 (ft-lb_f)
%Error= -12.7 %

3. Results from the present OLDMISS algorithm with correction factors equal to 1.0 are the same as above. This is because the PDOF makes the same angle with the vehicle surfaces (equal to zero in this case) for the two vehicles. Thus $C_{f1} = C_{f2}$ in equations (A.1).

4. The OLDMISS program is run with $C_{f1} = C_{f2} = 1.0$ and with vehicle-specific values of d_0 and d_0. The predicted profile is then used with eqns (C.1) to get the energies absorbed.

Vehicle #1 missing, Vehicle #2 available
L = 61.0 in.
C_1 = 28.5 in.
C_2 = 29.0 in.
C_3 = 29.5 in.
C_4 = 27.7 in.
C_5 = 23.2 in.
C_6 = 19.2 in.
E_{1est4} = 151111.5 (ft-lb_f)
%Error= -8.4 %

Vehicle #2 missing, Vehicle #1 available
L = 71.0 in.
C_1 = 24.3 in.
C_2 = 23.9 in.
C_3 = 23.8 in.
C_4 = 22.7 in.
C_5 = 21.2 in.
C_6 = 19.4 in.
E_{1est4} = 146238.9 (ft-lb_f)
%Error= 9.1 %

5. The proposed algorithm (equation (6.1)) is used with vehicle-specific values of d_0 and d_1 to obtain the estimates of energies absorbed. The estimated profile generation is not required for this calculation.

Vehicle #1 missing, Vehicle #2 available
From eqn. (6.1),

$$E_{1est5}=\frac{(d_1^2)_{veh2}}{(d_1^2)_{veh1}}\times E_2$$

$$=\frac{7.69^2}{7.24^2}\times 134077.3$$

$$=151262.3 \quad (ft\text{-}lb_f)$$

$$\%Error=-8.3\%$$

Vehicle #2 missing, Vehicle #1 available
From eqn. (6.1),

$$E_{2est5}=\frac{(d_1^2)_{veh1}}{(d_1^2)_{veh2}}\times E_1$$
$$=\frac{7.24^2}{7.69^2}\times 164923.5$$
$$=146186.4 \quad (ft\text{-}lb_f)$$
$$\%Error=9.0\%$$

Calspan Test #2 Side 90° Impact Ref [2]

Test description

This test involves a 90 degrees car-to-car impact involving two 1982 Chevrolet Citations. Vehicle #1 (3210 lb$_f$) was travelling at 17.08 mph and was struck on the left side by Vehicle #2 (3000 lb$_f$) travelling at a velocity of 34.16 mph.

Vehicle #1 '82 Citation (side impact):
Vehicle specific $d_0 = 30.00$ ($\sqrt{lb_f}$); $d_1 = 5.845$ ($\sqrt{lb_f}/in$) (From Appendix B)
Used in OLDMISS $A = 173.3$ (lf_f/in); $B = 57.1$ (lb_f/in^2) Ref [4]
Measured crushes
L = 86.0 in.
C_1 = 1.8 in.
C_2 = 16.3 in.
C_3 = 13.5 in.
C_4 = 13.0 in.
C_5 = 11.5 in.
C_6 = 0.5 in.

Vehicle #2 '82 Citation (front impact):
Vehicle specific $d_0 = 47.57$ ($\sqrt{lb_f}$); $d_1 = 7.69$ ($\sqrt{lb_f}/in$) Ref [5]
Used in OLDMISS $A = 373.0$ (lf_f/in); $B = 38.0$ (lb_f/in^2) Ref [4]
Measured crushes
L = 61.0 in.
C_1 = 2.3 in.
C_2 = 1.3 in.
C_3 = 1.0 in.
C_4 = 1.0 in.
C_5 = 0.5 in.
C_6 = 0.5 in.

1. Actual crush-energy absorbed by the two vehicles is calculated using equations (C.1) and vehicle specific values of d_0 and d_1 and actual measured crushes listed above. These are the values which would be generated by the CRASH3 program, if both vehicles are available for measurement. The values are:

   E_1 = 34153.65 ($ft\text{-}lb_f$)
   E_2 = 7880.5 ($ft\text{-}lb_f$)

2. The present OLDMISS results are obtained by running OLDMISS to obtain the predicted crushes and then using equations (C.1) and the A and B values (converted to d_0 and d_1) used in OLDMISS. The predicted crushes and calculated energies absorbed for the two possible cases are:

   Vehicle #1 missing, Vehicle #2 available
   L = 61.0 in.
   C_1 = 3.8 in.
   C_2 = 3.8 in.

C_3 = 4.2 in.
C_4 = 4.2 in.
C_5 = 4.4 in.
C_6 = 5.0 in.
E_{1est2} = 7611.6 (ft-lb$_f$)
%Error= -77.7 %

Vehicle #2 missing, Vehicle #1 available
L = 76.2 in.
C_1 = 11.7 in.
C_2 = 17.7 in.
C_3 = 19.1 in.
C_4 = 21.2 in.
C_5 = 20.6 in.
C_6 = 0.0 in.
E_{2est2} = 84652.2 (ft-lb$_f$)
%Error= 974 %

3. Results from the present OLDMISS algorithm with correction factors equal to 1.0 are the same as above. This is because the PDOF makes the same angle with the vehicle surfaces (equal to 26.6° in this case) for the two vehicles. Thus $C_{f1} = C_{f2}$ in equations (A.1).

4. The OLDMISS program is run with $C_{f1} = C_{f2} = 1.0$ and with vehicle-specific values of d_0 and d_0. The predicted profile is then used with eqns (C.1) to get the energies absorbed.

Vehicle #1 missing, Vehicle #2 available
L = 61.0 in.
C_1 = 6.4 in.
C_2 = 6.4 in.
C_3 = 7.3 in.
C_4 = 7.3 in.
C_5 = 7.8 in.
C_6 = 9.6 in.
E_{1est4} = 13610.3 (ft-lb$_f$)
%Error= -60.2 %

Vehicle #2 missing, Vehicle #1 available
L = 72.6 in.
C_1 = 3.5 in.
C_2 = 5.8 in.
C_3 = 6.4 in.
C_4 = 7.2 in.
C_5 = 6.9 in.
C_6 = 0.0 in.
E_{1est4} = 25385.4 (ft-lb$_f$)
%Error= 222.1 %

5. The proposed algorithm (equations (6.2) and (6.3)) are used with vehicle-specific values of d_0 and d_1 to obtain the estimates of energies absorbed. The estimated profile generation is not required for this calculation.

Vehicle #1 missing, Vehicle #2 available
From eqn. (6.1),

$$E_{1est5}=1.32\times\frac{(d_1^2)_{veh2}}{(d_1^2)_{veh1}}\times E_2$$
$$=1.32\times\frac{7.69^2}{5.84^2}\times 7880.5$$
$$=18067.14 \quad (ft\text{-}lb_f)$$
$$\%Error=-47.1\%$$

Vehicle #2 missing, Vehicle #1 available
From eqn. (6.1),

$$E_{2est5}=\frac{(d_1^2)_{veh1}}{(d_1^2)_{veh2}}\times\frac{E_1}{1.32}$$
$$=\frac{5.84^2}{7.69^2}\times\frac{34153.7}{1.32}$$
$$=14897.11 \quad (ft\text{-}lb_f)$$
$$\%Error=89.0\%$$

6. The proposed algorithm with enhancement (equations (11.2) and (11.3)) are used with vehicle-specific values of d_0 and d_1 to obtain the estimates of energies absorbed.

Vehicle #1 missing, Vehicle #2 available
From eqn. (11.2),

$$E_{1est5}=2.1\times\frac{(d_1^2)_{veh2}}{(d_1^2)_{veh1}}\times E_2$$
$$=2.1\times\frac{7.69^2}{5.84^2}\times 7880.5$$
$$=28743.18 \quad (ft\text{-}lb_f)$$
$$\%Error=-16.9\%$$

Vehicle #2 missing, Vehicle #1 available
From eqn. (11.3),

$$E_{2est5}=\frac{(d_1^2)_{veh1}}{(d_1^2)_{veh2}}\times\frac{E_1}{2.1}$$
$$=\frac{5.84^2}{7.69^2}\times\frac{34153.7}{2.1}$$
$$=9363.90 \quad (ft\text{-}lb_f)$$
$$\%Error=20.4\%$$

Calspan Test #4 Front-Rear 170° Impact Ref [2]

Test description

This test involves a 170 degrees car-to-car impact involving a 1974 Ford Torino (Veh #1) and a 1974 Ford Pinto (Veh #2). Vehicle #1 (4980 lb_f) was travelling at 38.7 mph and struck the rear of the stationary Vehicle #2 (3190 lb_f) offset at 10°. This is the RICSAC Test #4.

Vehicle #1 '74 Torino (front impact):
Vehicle specific $d_0 = 48.78$ ($\sqrt{lb_f}$); $d_1 = 7.35$ ($\sqrt{lb_f}$/in) Ref [5]
Used in OLDMISS $A = 355.9$ (lf_f/in); $B = 33.8$ (lb_f/in^2) Ref [4]
Measured crushes
L = 72.0 in.
C_1 = 0.0 in.
C_2 = 2.5 in.
C_3 = 5.2 in.
C_4 = 8.9 in.
C_5 = 13.9 in.
C_6 = 18.3 in.

Vehicle #2 '74 Pinto (rear impact):
Vehicle specific $d_0 = 44.26$ ($\sqrt{lb_f}$); $d_1 = 5.21$ ($\sqrt{lb_f}$/in) Ref [5]
Used in OLDMISS $A = 390.5$ (lf_f/in); $B = 40.7$ (lb_f/in^2) Ref [4]
Measured crushes
L = 63.0 in.
C_1 = 36.0 in.
C_2 = 28.1 in.
C_3 = 23.9 in.
C_4 = 15.5 in.
C_5 = 12.1 in.
C_6 = 4.5 in.

1. Actual crush-energy absorbed by the two vehicles is calculated using equations (C.1) and vehicle specific values of d_0 and d_1 and actual measured crushes listed above. These are the values which would be generated by the CRASH3 program, if both vehicles are available for measurement. The values are:

   E_1 = 39147.3 (ft-lb_f)
   E_2 = 64530.7 (ft-lb_f)

2. The present OLDMISS results are obtained by running OLDMISS to obtain the predicted crushes and then using equations (C.1) and the A and B values (converted to d_0 and d_1) used in OLDMISS. The predicted crushes and calculated energies absorbed for the two possible cases are:

   Vehicle #1 missing, Vehicle #2 available
   L = 64.0 in.
   C_1 = 44.4 in.
   C_2 = 34.9 in.
   C_3 = 29.8 in.
   C_4 = 22.1 in.
   C_5 = 15.6 in.
   C_6 = 6.4 in.
   E_{1est2} = 126895 (ft-lb_f)
   %Error= 224.1 %

   Vehicle #2 missing, Vehicle #1 available
   L = 67.2 in.
   C_1 = 0.0 in.
   C_2 = 1.8 in.

C_3 = 4.2 in.
C_4 = 7.4 in.
C_5 = 11.8 in.
C_6 = 15.7 in.
E_{2est2} = 32447.6 (ft-lb$_f$)
%Error= -49.7 %

3. The OLDMISS program is run with $C_{f1} = C_{f2} = 1.0$ and the predicted profile is then used with eqns (C.1) to get the energies absorbed. Stiffness coeff. A and B used in the present OLDMISS is used.

Vehicle #1 missing, Vehicle #2 available
L = 64.0 in.
C_1 = 43.5 in.
C_2 = 34.2 in.
C_3 = 29.2 in.
C_4 = 21.6 in.
C_5 = 15.2 in.
C_6 = 6.2 in.
E_{1est3} = 123023 (ft-lb$_f$)
%Error= 214 %

Vehicle #2 missing, Vehicle #1 available
L = 67.2 in.
C_1 = 0.0 in.
C_2 = 2.0 in.
C_3 = 4.4 in.
C_4 = 7.7 in.
C_5 = 12.1 in.
C_6 = 16.1 in.
E_{1est3} = 33432.2 (ft-lb$_f$)
%Error= -48.2 %

4. The OLDMISS program is run with $C_{f1} = C_{f2} = 1.0$ and with vehicle-specific values of d_0 and d_0. The predicted profile is then used with eqns (C.1) to get the energies absorbed.

Vehicle #1 missing, Vehicle #2 available
L = 64.0 in.
C_1 = 15.4 in.
C_2 = 11.5 in.
C_3 = 9.4 in.
C_4 = 6.2 in.
C_5 = 3.6 in.
C_6 = 0.0 in.
E_{1est4} = 32046.4 (ft-lb$_f$)
%Error= -18.2 %

Vehicle #2 missing, Vehicle #1 available
L = 67.2 in.
C_1 = 5.7 in.
C_2 = 11.0 in.
C_3 = 16.7 in.
C_4 = 24.6 in.
C_5 = 35.3 in.
C_6 = 44.7 in.
E_{1est4} = 83444 (ft-lb$_f$)
%Error= 29.3 %

5. The proposed algorithm (equations (6.2) and (6.3)) are used with vehicle-specific values of d_0 and d_1 to obtain the estimates of energies absorbed. The estimated profile generation is not required for this calculation.

Vehicle #1 missing, Vehicle #2 available
From eqn. (6.1),

$$E_{1est5}=\frac{(d_1^2)_{veh2}}{(d_1^2)_{veh1}}\times E_2$$
$$=\frac{5.21^2}{7.35^2}\times 64530.7$$
$$=32420.64 \quad (ft\text{-}lb_f)$$
$$\%Error=-17.2\%$$

Vehicle #2 missing, Vehicle #1 available
From eqn. (6.1),

$$E_{2est5}=\frac{(d_1^2)_{veh1}}{(d_1^2)_{veh2}}\times E_1$$
$$=\frac{7.35^2}{5.21^2}\times 39147.3$$
$$=77919.57 \quad (ft\text{-}lb_f)$$
$$\%Error=20.7\%$$

Calspan Test #3 Side 60° Impact Ref [2]
Test description
This test involves a 60 degrees car-to-car impact involving two 1982 Chevrolet Citations. Vehicle #1 (3140 lb_f) was travelling at 12.99 mph and was struck on the left side by Vehicle #2 (3000 lb_f) travelling at a velocity of 25.98 mph.

Vehicle #1 '82 Citation (side impact):
Vehicle specific $d_0 = 30.00$ ($\sqrt{lb_f}$); $d_1 = 5.845$ ($\sqrt{lb_f}$/in) (From Appendix B)
Used in OLDMIS $A = 173.3$ (lf_f/in); $B = 57.1$ (lb_f/in^2) Ref [4]
Measured crushes
L = 84.0 in.
C_1 = 0.0 in.
C_2 = 6.5 in.
C_3 = 13.5 in.
C_4 = 15.6 in.
C_5 = 13.5 in.
C_6 = 0.2 in.

Vehicle #2 '82 Citation (front impact):
Vehicle specific $d_0 = 47.57$ ($\sqrt{lb_f}$); $d_1 = 7.69$ ($\sqrt{lb_f}$/in) Ref [5]
Used in OLDMISS $A = 373.0$ (lf_f/in); $B = 38.0$ (lb_f/in^2) Ref [4]
Measured crushes
L = 61.0 in.
C_1 = 1.0 in.
C_2 = 1.4 in.
C_3 = 1.0 in.
C_4 = 0.5 in.
C_5 = 0.1 in.
C_6 = 0.0 in.

1. Actual crush-energy absorbed by the two vehicles is calculated using equations (C.1) and vehicle specific values of d_0 and d_1 and actual measured crushes listed above. These are the values which would be generated by the

CRASH3 program, if both vehicles are available for measurement. The values are:

E_1 = 29671.9 (ft-lb$_f$)
E_2 = 7161.4 (ft-lb$_f$)

2. The present OLDMISS results are obtained by running OLDMISS to obtain the predicted crushes and then using equations (C.1) and the A and B values (converted to d_0 and d_1) used in OLDMISS. The predicted crushes and calculated energies absorbed for the two possible cases are:

Vehicle #1 missing, Vehicle #2 available
L = 53.3 in.
C_1 = 2.2 in.
C_2 = 2.2 in.
C_3 = 2.4 in.
C_4 = 2.7 in.
C_5 = 2.9 in.
C_6 = 2.7 in.
E_{1est2} = 3935.5 (ft-lb$_f$)
%Error= -86.7 %
Vehicle #2 missing, Vehicle #1 available
L = 67.7 in.
C_1 = 0.0 in.
C_2 = 12.3 in.
C_3 = 27.1 in.
C_4 = 36.8 in.
C_5 = 39.1 in.
C_6 = 34.6 in.
E_{2est2} = 158012.7 (ft-lb$_f$)
%Error= 2106 %

3. The OLDMISS program is run with $C_{f1} = C_{f2} = 1.0$ and the predicted profile is then used with eqns (C.1) to get the energies absorbed. Stiffness coeff. A and B used in the present OLDMISS is used.

Vehicle #1 missing, Vehicle #2 available
L = 53.3 in.
C_1 = 4.4 in.
C_2 = 4.5 in.
C_3 = 4.8 in.
C_4 = 5.2 in.
C_5 = 5.5 in.
C_6 = 5.2 in.
E_{1est3} = 8123.4 (ft-lb$_f$)
%Error= -72.6 %
Vehicle #2 missing, Vehicle #1 available
L = 67.7 in.
C_1 = 0.0 in.
C_2 = 5.5 in.
C_3 = 15.8 in.
C_4 = 22.6 in.
C_5 = 24.1 in.
C_6 = 21.0 in.
E_{1est3} = 76800.3 (ft-lb$_f$)
%Error= 972.4 %

4. The OLDMISS program is run with $C_{f1} = C_{f2} = 1.0$ and with vehicle-specific values of d_0 and d_0. The predicted profile is then used with eqns (C.1) to get the energies absorbed.

Vehicle #1 missing, Vehicle #2 available
L = 53.3 in.
C_1 = 7.1 in.
C_2 = 7.3 in.
C_3 = 8.1 in.
C_4 = 9.1 in.
C_5 = 9.9 in.
C_6 = 9.1 in.
E_{1est4} = 14170.3 (ft-lb_f)
%Error= -52.2 %

Vehicle #2 missing, Vehicle #1 available
L = 67.7 in.
C_1 = 0.0 in.
C_2 = 1.2 in.
C_3 = 5.2 in.
C_4 = 7.8 in.
C_5 = 8.4 in.
C_6 = 7.2 in.
E_{1est4} = 23251.8 (ft-lb_f)
%Error= 224.7 %

5. The proposed algorithm (equations (6.2) and (6.3)) are used with vehicle-specific values of d_0 and d_1 to obtain the estimates of energies absorbed. The estimated profile generation is not required for this calculation.

Vehicle #1 missing, Vehicle #2 available
From eqn. (6.1),

$$E_{1est5}=1.32\times\frac{(d_1^2)_{veh2}}{(d_1^2)_{veh1}}\times E_2$$
$$=1.32\times\frac{7.69^2}{5.84^2}\times 7161.4$$
$$=16418.5 \quad (ft\text{-}lb_f)$$
$$\%Error=-44.7\%$$

Vehicle #2 missing, Vehicle #1 available
From eqn. (6.1),

$$E_{2est5}=\frac{(d_1^2)_{veh1}}{(d_1^2)_{veh2}}\times\frac{E_1}{1.32}$$
$$=\frac{5.84^2}{7.69^2}\times\frac{29671.9}{1.32}$$
$$=12942.2 \quad (ft\text{-}lb_f)$$
$$\%Error=80.7\%$$

6. The proposed algorithm with enhancement (equations (11.2) and (11.3)) are used with vehicle-specific values of d_0 and d_1 to obtain the estimates of energies absorbed.

Vehicle #1 missing, Vehicle #2 available
From eqn. (11.2),

$$
\begin{aligned}
E_{1est5} &= 2.1\times\frac{(d_1^2)_{veh2}}{(d_1^2)_{veh1}}\times E_2 \\
&= 2.1\times\frac{7.69^2}{5.84^2}\times 7161.4 \\
&= 26120.34 \quad (ft\text{-}lb_f)
\end{aligned}
$$

$\%Error=-13.1\%$

Vehicle #2 missing, Vehicle #1 available
From eqn. (11.3),

$$
\begin{aligned}
E_{2est5} &= \frac{(d_1^2)_{veh1}}{(d_1^2)_{veh2}}\times\frac{E_1}{2.1} \\
&= \frac{5.84^2}{7.69^2}\times\frac{29671.9}{2.1} \\
&= 8135.09 \quad (ft\text{-}lb_f)
\end{aligned}
$$

$\%Error=15.1\%$

Test #547 Side 90° Impact
Test description
This test involves a 90 degrees car-to-car impact involving a Chevrolet Citation (vehicle #1) and a Volkswagen Rabbit (vehicle #2). Vehicle #2 (2600 lb_f) was travelling at 13.4 mph and was struck on the left side by Vehicle #1 (3000 lb_f) travelling at a velocity of 28.6 mph.

Vehicle #1 '82 Citation (front impact):
Vehicle specific $d_0 = 47.57$ ($\sqrt{lb_f}$); $d_1 = 7.69$ ($\sqrt{lb_f}$/in) Ref [5]
Used in OLDMISS A = 373.0 (lf_f/in); B = 38.0 (lb_f/in^2) Ref [4]
Measured crushes
L = 68.1 in.
C_1 = 1.7 in.
C_2 = 1.7 in.
C_3 = 1.4 in.
C_4 = 1.4 in.
C_5 = 1.3 in.
C_6 = 1.3 in.

Vehicle #2 '82 Rabbit (Side impact):
Vehicle specific $d_0 = 30.00$ ($\sqrt{lb_f}$); $d_1 = 6.75$ ($\sqrt{lb_f}$/in) (from Appendix B)
Used in OLDMISS A = 77.2 (lf_f/in); B = 36.7 (lb_f/in^2) Ref [4]
Measured crushes
L = 72.0 in.
C_1 = 1.9 in.
C_2 = 10.6 in.
C_3 = 11.2 in.
C_4 = 11.5 in.
C_5 = 11.2 in.
C_6 = 6.7 in.

1. Actual crush-energy absorbed by the two vehicles is calculated using equations (C.1) and vehicle specific values of d_0 and d_1 and actual measured crushes listed above. These are the values which would be generated by the CRASH3 program, if both vehicles are available for measurement. The values are:
   E_1 = 9813.5 ($ft\text{-}lb_f$)
   E_2 = 28327.2 ($ft\text{-}lb_f$)

2. The present OLDMISS results are obtained by running OLDMISS to obtain the predicted crushes and then using equations (C.1) and the A and B values (converted to d_0 and d_1) used in OLDMISS. The predicted crushes and calculated energies absorbed for the two possible cases are:

   Vehicle #1 missing, Vehicle #2 available
   L = 72.0 in.
   C_1 = 0.0 in.
   C_2 = 3.0 in.
   C_3 = 3.3 in.
   C_4 = 3.0 in.
   C_5 = 2.5 in.
   C_6 = 0.0 in.
   E_{1est2} = 17007.2 (ft-lb_f)
   %Error= 73.3 %

   Vehicle #2 missing, Vehicle #1 available
   L = 68.1 in.
   C_1 = 9.4 in.
   C_2 = 9.4 in.
   C_3 = 9.5 in.
   C_4 = 9.5 in.
   C_5 = 9.8 in.
   C_6 = 9.8 in.
   E_{2est2} = 14168.9 (ft-lb_f)
   %Error= -50 %

3. Results from the present OLDMISS algorithm with correction factors equal to 1.0 are the same as above. This is because the PDOF makes the same angle with the vehicle surfaces (equal to 25.1° in this case) for the two vehicles. Thus $C_{f1} = C_{f2}$ in equations (A.1).

4. The OLDMISS program is run with $C_{f1} = C_{f2} = 1.0$ and with vehicle-specific values of d_0 and d_0. The predicted profile is then used with eqns (C.1) to get the energies absorbed.

   Vehicle #1 missing, Vehicle #2 available
   L = 72.0 in.
   C_1 = 2.4 in.
   C_2 = 5.9 in.
   C_3 = 6.1 in.
   C_4 = 5.9 in.
   C_5 = 5.4 in.
   C_6 = 0.0 in.
   E_{1est4} = 22224.1 (ft-lb_f)
   %Error= 126.5 %

   Vehicle #2 missing, Vehicle #1 available
   L = 68.1 in.
   C_1 = 5.3 in.
   C_2 = 5.3 in.
   C_3 = 5.4 in.
   C_4 = 5.4 in.
   C_5 = 5.8 in.
   C_6 = 5.8 in.
   E_{1est4} = 12764.2 (ft-lb_f)
   %Error= -50 %

5. The proposed algorithm (equations (6.2) and (6.3)) are used with vehicle-specific values of d_0 and d_1 to obtain the estimates of energies absorbed. The estimated profile generation is not required for this calculation.

Vehicle #1 missing, Vehicle #2 available
From eqn. (6.1),

$$E_{1est5}=\frac{(d_1^2)_{veh2}}{(d_1^2)_{veh1}}\times\frac{E_2}{1.32}$$
$$=\frac{6.75^2}{7.69^2}\times\frac{28327.2}{1.32}$$
$$=16478.08\quad(ft\text{-}lb_f)$$
$$\%Error=67.9\%$$

Vehicle #2 missing, Vehicle #1 available
From eqn. (6.1),

$$E_{2est5}=1.32\times\frac{(d_1^2)_{veh1}}{(d_1^2)_{veh2}}\times E_1$$
$$=1.32\times\frac{7.69^2}{6.75^2}\times9813.5$$
$$=16870.23\quad(ft\text{-}lb_f)$$
$$\%Error=-40.4\%$$

6. The proposed algorithm with enhancement (equations (11.2) and (11.3)) are used with vehicle-specific values of d_0 and d_1 to obtain the estimates of energies absorbed.

Vehicle #1 missing, Vehicle #2 available
From eqn. (11.3),

$$E_{1est5}=\frac{(d_1^2)_{veh2}}{(d_1^2)_{veh1}}\times\frac{E_2}{2.1}$$
$$=\frac{6.75^2}{7.69^2}\times\frac{28327.2}{2.1}$$
$$=10357.65\quad(ft\text{-}lb_f)$$
$$\%Error=6.9\%$$

Vehicle #2 missing, Vehicle #1 available
From eqn. (11.2),

$$E_{2est5}=2.1\times\frac{(d_1^2)_{veh1}}{(d_1^2)_{veh2}}\times E_1$$
$$=2.1\times\frac{7.69^2}{6.75^2}\times9813.5$$
$$=26839.0\quad(ft\text{-}lb_f)$$
$$\%Error=-6.5\%$$

Test #570 Side 90° Impact

Test description

This test involves a 90 degrees car-to-car impact involving two Chevrolet Citations. Vehicle #2 (3049 lb_f) was travelling at 13 mph and was struck on the left side by Vehicle #1 (2996 lb_f) travelling at a velocity of 25.4 mph.

Vehicle #1 '82 Citation (front impact):
Vehicle specific $d_0 = 47.57$ ($\sqrt{lb_f}$); $d_1 = 7.69$ ($\sqrt{lb_f}$/in) Ref [5]
Used in OLDMISS A = 373.0 (lf_f/in); B = 38.0 (lb_f/in^2) Ref [4]
Measured crushes
L = 63.0 in.
C_1 = 1.0 in.
C_2 = 1.0 in.
C_3 = 1.3 in.
C_4 = 1.5 in.
C_5 = 2.3 in.
C_6 = 1.8 in.

Vehicle #2 '82 Citation (Side impact):
Vehicle specific $d_0 = 30.00$ ($\sqrt{lb_f}$); $d_1 = 5.845$ ($\sqrt{lb_f}$/in) (From Appendix B)
Used in OLDMISS A = 173.3 (lf_f/in); B = 57.1 (lb_f/in^2) Ref [4]
Measured crushes
L = 78.0 in.
C_1 = 0.9 in.
C_2 = 11.0 in.
C_3 = 12.1 in.
C_4 = 11.9 in.
C_5 = 8.6 in.
C_6 = 2.3 in.

1. Actual crush-energy absorbed by the two vehicles is calculated using equations (C.1) and vehicle specific values of d_0 and d_1 and actual measured crushes listed above. These are the values which would be generated by the CRASH3 program, if both vehicles are available for measurement. The values are:
   E_1 = 9199.1 (ft-lb_f)
   E_2 = 23452.3 (ft-lb_f)

2. The present OLDMISS results are obtained by running OLDMISS to obtain the predicted crushes and then using equations (C.1) and the A and B values (converted to d_0 and d_1) used in OLDMISS. The predicted crushes and calculated energies absorbed for the two possible cases are:

   Vehicle #1 missing, Vehicle #2 available
   L = 72.6 in.
   C_1 = 0.0 in.
   C_2 = 8.3 in.
   C_3 = 13.6 in.
   C_4 = 14.6 in.
   C_5 = 13.3 in.
   C_6 = 2.2 in.
   E_{1est2} = 48053.0 (ft-lb_f)
   %Error= 422 %
   Vehicle #2 missing, Vehicle #1 available
   L = 63.0 in.
   C_1 = 4.7 in.
   C_2 = 5.0 in.
   C_3 = 4.5 in.
   C_4 = 4.4 in.
   C_5 = 4.2 in.
   C_6 = 4.2 in.

E_{2est2} = 8543.2 (ft-lb$_f$)
%Error= -63.6 %

3. Results from the present OLDMISS algorithm with correction factors equal to 1.0 are the same as above. This is because the PDOF makes the same angle with the vehicle surfaces (equal to 27.1° in this case) for the two vehicles. Thus $C_{f1} = C_{f2}$ in equations (A.1).

4. The OLDMISS program is run with $C_{f1} = C_{f2} = 1.0$ and with vehicle-specific values of d_0 and d_0. The predicted profile is then used with eqns (C.1) to get the energies absorbed.

Vehicle #1 missing, Vehicle #2 available
L = 72.6 in.
C_1 = 0.0 in.
C_2 = 2.1 in.
C_3 = 4.1 in.
C_4 = 4.5 in.
C_5 = 4.0 in.
C_6 = 0.0 in.
E_{1est4} = 15260.1 (ft-lb$_f$)
%Error= 66 %

Vehicle #2 missing, Vehicle #1 available
L = 63.0 in.
C_1 = 8.7 in.
C_2 = 9.6 in.
C_3 = 8.2 in.
C_4 = 7.8 in.
C_5 = 7.3 in.
C_6 = 7.3 in.
E_{1est4} = 15946.2 (ft-lb$_f$)
%Error= -32 %

5. The proposed algorithm (equations (6.2) and (6.3)) are used with vehicle-specific values of d_0 and d_1 to obtain the estimates of energies absorbed. The estimated profile generation is not required for this calculation.

Vehicle #1 missing, Vehicle #2 available
From eqn. (6.1),

$$\begin{aligned} E_{1est5} &= \frac{(d_1^2)_{veh2}}{(d_1^2)_{veh1}} \times \frac{E_2}{1.32} \\ &= \frac{5.84^2}{7.69^2} \times \frac{23452.3}{1.32} \\ &= 10229.4 \quad (ft\text{-}lb_f) \end{aligned}$$

$\%Error = 11.2\%$

Vehicle #2 missing, Vehicle #1 available
From eqn. (6.1),

$$\begin{aligned} E_{2est5} &= 1.32 \times \frac{(d_1^2)_{veh1}}{(d_1^2)_{veh2}} \times E_1 \\ &= 1.32 \times \frac{7.69^2}{5.84^2} \times 9199.1 \\ &= 21090.2 \quad (ft\text{-}lb_f) \end{aligned}$$

$\%Error = -10.1\%$

6. The proposed algorithm with enhancement (equations (11.2) and (11.3)) are used with vehicle-specific values of d_0 and d_1 to obtain the estimates of energies absorbed.

Vehicle #1 missing, Vehicle #2 available

From eqn. (11.3),

$$E_{1est5}=\frac{(d_1^2)_{veh2}}{(d_1^2)_{veh1}}\times\frac{E_2}{2.1}$$

$$=\frac{5.84^2}{7.69^2}\times\frac{23452.3}{2.1}$$

$$=6429.91\quad(ft\text{-}lb_f)$$

$$\%Error=-29.1\%$$

Vehicle #2 missing, Vehicle #1 available

From eqn. (11.2),

$$E_{2est5}=2.1\times\frac{(d_1^2)_{veh1}}{(d_1^2)_{veh2}}\times E_1$$

$$=2.1\times\frac{7.69^2}{5.84^2}\times 9199.1$$

$$=33552.6\quad(ft\text{-}lb_f)$$

$$\%Error=41.2\%$$

Test	Missing Vehicle	Missing Vehicles Damaged Side	% Error† in E				
			Method of Estimating E				
			2	3	4	5	6
Calspan #1	1	Front	-26.2	-26.2	-8.4	-8.3	-8.3
	2	Front	-12.7	-12.7	9.1	9.0	9.0
Calspan #4	1	Front	224.1	214.0	-18.2	-17.2	-17.2
	2	Rear	-49.7	-48.2	29.3	20.7	20.7
Calspan #2	1	Side	-77.7	-77.7	-60.2	-47.1	-16.9
	2	Front	974.0	974.0	221.1	89.0	20.4
Calspan #3	1	Side	-86.7	-72.6	-52.2	-44.7	-13.1
	2	Front	2106.0	972.4	224.7	80.7	15.1
Test #547	2	Side	-50.0	-50.0	-50.0	-40.4	-6.5
	1	Front	73.3	73.3	126.5	67.9	6.9
Test #570	2	Side	-63.6	-63.6	-32.0	-10.1	41.2
	1	Front	422.0	422.0	66.0	11.2	-29.1
Side Impact - RMS Error			835.7	511.8	127.3	56.0	21.6
Side Impact - Average |Error|			481.7	338.2	104.1	48.9	18.7

Method of estimating E

2	Present OLDMISS
3	Present OLDMISS with $C_{f1}=C_{f2}=1.0$
4	Present OLDMISS with $C_{f1}=C_{f2}=1.0$ and vehicle-specific d_0 and d_1
5	Proposed Algorithm

† The error is a percentage of the 'actual' energy absorbed by the missing vehicle (calculated by integrating the measured damage profile and using vehicle-specific crush coefficients).

Table D.1 Reconstruction Errors in E

Appendix E
Reconstruction of RICSAC Tests

The reconstruction of the twelve RICSAC tests are described below. Each RICSAC test is studied as two cases: vehicle 1 available, vehicle 2 missing; and vehicle 2 available, vehicle 1 missing. For each case, the following is listed:

1)The test data and measured crush profiles.

2)The energy absorbed by the vehicles (obtained by integrating the measured crush profiles (Equation (C.1)) and using vehicle-specific values of crush coeff. d_0 and d_1).

3)The crush profiles produced by the present OLDMISS, and the energy absorbed by the vehicle, as indicated by the OLDMISS program. The output files from OLDMISS are listed in section E.13 of this Appendix.

4)The energy absorbed by the missing vehicle, as indicated by the proposed algorithm.

E.1 RICSAC TEST # 1

This test involves an offset oblique front-to-side car-to-car impact of a 1974 Chevelle Malibu (4650 lbs.) and a 1974 Ford Pinto (3110 lbs.) At impact, each vehicle was travelling at 19.8 mph. The measured crushes and crush coeff. are:

Vehicle #1 '74 Chevelle (front impact):
Vehicle specific $d_0 = 59.80$ ($\sqrt{lb_f}$); $d_1 = 6.95$ ($\sqrt{lb_f}$/in) Ref [6]
Used in OLDMISS A = 355.9 (lf_f/in); B = 33.8 (lb_f/in^2) Ref [4]
Measured crushes:

L = 46.0 in.
C_1 = 4.0 in.
C_2 = 5.5 in.
C_3 = 7.0 in.
C_4 = 10.2 in.
C_5 = 12.1 in.
C_6 = 14.8 in.
D = 14.3 in.

Vehicle #2 '74 Pinto (side impact):
Vehicle specific $d_0 = 30.0$ ($\sqrt{lb_f}$); $d_1 = 8.82$ ($\sqrt{lb_f}$/in) Ref [5]
Used in OLDMISS A = 140.4 (lf_f/in); B = 66.7 (lb_f/in^2) Ref [4]
Measured crushes:

L = 113.3 in.
C_1 = 0.5 in.
C_2 = 12.0 in.
C_3 = 10.6 in.
C_4 = 11.8 in.
C_5 = 9.0 in.
C_6 = 4.1 in.
D = 21.8 in.

1. Actual crush-energy absorbed by the two vehicles is calculated using equations (C.1) and vehicle specific values of d_0 and d_1 and actual measured crushes listed above. These are the values which would be generated by the CRASH3 program, if both vehicles are available for measurement. The values are:

   E_1 = 29139.3 (ft-lb_f)
   E_2 = 60664.8 (ft-lb_f)

2. The present OLDMISS results are obtained by running OLDMISS to obtain the predicted crushes and the absorbed energies. The predicted crushes and energies absorbed for the two possible cases are:

Vehicle #1 available, Vehicle #2 missing

L = 47.2 in.
C_1 = 2.0 in.
C_2 = 2.5 in.
C_3 = 2.9 in.
C_4 = 3.8 in.
C_5 = 4.3 in.
C_6 = 5.1 in.
E_{2est} = 8223.2 $(ft\text{-}lb_f)$
%Error= -86.4 %

Vehicle #2 available, Vehicle #1 missing

L = 71.8 in.
C_1 = 64.4 in.
C_2 = 60.5 in.
C_3 = 59.4 in.
C_4 = 64.0 in.
C_5 = 40.7 in.
C_6 = 3.5 in.
E_{1est} = 558360.8 $(ft\text{-}lb_f)$
%Error= 1816.2 %

5. The proposed algorithm (equations (11.2) and (11.3)) is used with vehicle-specific values of d_0 and d_1 to obtain the estimates of energies absorbed. The estimated profile generation is not required for this calculation.

Vehicle #1 available, Vehicle #2 missing

From eqn. (11.2),

$$
\begin{aligned}
E_2 &= 2.1\times\frac{(d_1^2)_{veh1}}{(d_1^2)_{veh2}}\times E_1\\
&= 2.1\times\frac{6.95^2}{8.82^2}\times 29139.3\\
&= 37995.4 \quad (ft\text{-}lb_f)
\end{aligned}
$$

%Error =-37.4 %

Vehicle #2 available, Vehicle #1 missing

From eqn. (11.3),

$$
\begin{aligned}
E_1 &= \frac{(d_1^2)_{veh2}}{(d_1^2)_{veh1}}\times\frac{E_2}{2.1}\\
&= \frac{8.82^2}{6.95^2}\times\frac{60664.8}{2.1}\\
&= 46524.8 \quad (ft\text{-}lb_f)
\end{aligned}
$$

%Error = 59.7 %

E.2 RICSAC TEST # 2

This test involves an offset oblique front-to-side car-to-car impact of a 1974 Chevelle Malibu (4710 lbs.) and a 1974 Ford Pinto (3260 lbs.) At impact, each vehicle was travelling at 31.5 mph. The measured crushes and crush coeff. are:

Vehicle #1 '74 Chevelle (front impact):
Vehicle specific $d_0 = 59.80$ ($\sqrt{lb_f}$); $d_1 = 6.95$ ($\sqrt{lb_f}/in$) Ref [6]
Used in OLDMISS $A = 355.9$ (lf_f/in); $B = 33.8$ (lb_f/in^2) Ref [4]
Measured crushes:

L = 75.5 in.
C_1 = .5 in.
C_2 = 2.4 in.
C_3 = 3.7 in.
C_4 = 6.9 in.
C_5 = 12.0 in.
C_6 = 16.5 in.
D = .0 in.

Vehicle #2 '74 Pinto (side impact):
Vehicle specific $d_0 = 30.0$ ($\sqrt{lb_f}$); $d_1 = 8.82$ ($\sqrt{lb_f}/in$) Ref [5]
Used in OLDMISS $A = 140.4$ (lf_f/in); $B = 66.7$ (lb_f/in^2) Ref [4]
Measured crushes:

L = 118.5 in.
C_1 = 6.8 in.
C_2 = 22.8 in.
C_3 = 23.5 in.
C_4 = 21.3 in.
C_5 = 10.0 in.
C_6 = .0 in.
D = 13.7 in.

1. Actual crush-energy absorbed by the two vehicles is calculated using equations (C.1) and vehicle specific values of d_0 and d_1 and actual measured crushes listed above. These are the values which would be generated by the CRASH3 program, if both vehicles are available for measurement. The values are:

   E_1 = 39011.2 ($ft\text{-}lb_f$)
   E_2 = 166939.4 ($ft\text{-}lb_f$)

2. The present OLDMISS results are obtained by running OLDMISS to obtain the predicted crushes and the absorbed energies. The predicted crushes and energies absorbed for the two possible cases are:
   Vehicle #1 available, Vehicle #2 missing
   L = 73.6 in.
   C_1 = 1.2 in.
   C_2 = 1.8 in.
   C_3 = 2.2 in.
   C_4 = 3.1 in.
   C_5 = 4.7 in.
   C_6 = 6.0 in.
   E_{2est} = 11769.1 ($ft\text{-}lb_f$)
   %Error= -93.0 %
   Vehicle #2 available, Vehicle #1 missing
   L = 71.8 in.
   C_1 = 121.4 in.
   C_2 = 128.8 in.
   C_3 = 133.0 in.
   C_4 = 130.6 in.
   C_5 = 93.8 in.
   C_6 = 39.7 in.
   E_{1est} = 2159652.0 ($ft\text{-}lb_f$)
   %Error= 5436.0 %

5. The proposed algorithm (equations (11.2) and (11.3)) is used with vehicle-specific values of d_0 and d_1 to obtain the estimates of energies absorbed. The estimated profile generation is not required for this calculation.
   Vehicle #1 available, Vehicle #2 missing
   From eqn. (11.2),

$$E_2=2.1\times\frac{(d_1^2)_{veh1}}{(d_1^2)_{veh2}}\times E_1$$
$$=2.1\times\frac{6.95^2}{8.82^2}\times 39011.2$$
$$=50867.6 \quad (ft\text{-}lb_f)$$

%Error =-69.5 %

Vehicle #2 available, Vehicle #1 missing
From eqn. (11.3),

$$E_1=\frac{(d_1^2)_{veh2}}{(d_1^2)_{veh1}}\times\frac{E_2}{2.1}$$
$$=\frac{8.82^2}{6.95^2}\times\frac{166939.4}{2.1}$$
$$=128028.6 \quad (ft\text{-}lb_f)$$

%Error = 228.2 %

E.3 RICSAC TEST # 3

This test involves an offset oblique front-to-rear car-to-car impact of a 1974 Ford Torino (4980 lbs.) and a 1974 Ford Pinto (3140 lbs.) At impact, the bullet vehicle was travelling at 21.2 mph. The measured crushes and crush coeff. are:

Vehicle #1 '74 Torino (front impact):
Vehicle specific d_0 = 61.54 ($\sqrt{lb_f}$); d_1 = 6.45 ($\sqrt{lb_f}$/in) Ref [6]
Used in OLDMISS A = 355.9 (lf_f/in); B = 33.8 (lb_f/in^2) Ref [4]
Measured crushes:

L = 30.0 in.
C_1 = 2.0 in.
C_2 = 2.0 in.
C_3 = 1.5 in.
C_4 = 1.8 in.
C_5 = 2.0 in.
C_6 = 2.3 in.
D = 22.0 in.

Vehicle #2 '74 Pinto (rear impact):
Vehicle specific d_0 = 44.26 ($\sqrt{lb_f}$); d_1 = 5.21 ($\sqrt{lb_f}$/in) Ref [5]
Used in OLDMISS A = 390.5 (lf_f/in); B = 40.7 (lb_f/in^2) Ref [4]
Measured crushes:

L = 30.0 in.
C_1 = 6.5 in.
C_2 = 6.8 in.
C_3 = 5.8 in.
C_4 = 5.0 in.
C_5 = 3.8 in.
C_6 = 3.0 in.
D = -5.0 in.

1. Actual crush-energy absorbed by the two vehicles is calculated using equations (C.1) and vehicle specific values of d_0 and d_1 and actual measured crushes listed above. These are the values which would be generated by the CRASH3 program, if both vehicles are available for measurement. The values are:

   E_1 = 6779.4 (ft-lb_f)
   E_2 = 6414.7 (ft-lb_f)

2. The present OLDMISS results are obtained by running OLDMISS to obtain the predicted crushes and the absorbed energies. The predicted crushes and energies absorbed for the two possible cases are:

   Vehicle #1 available, Vehicle #2 missing
   L = 30.5 in.
   C_1 = .5 in.
   C_2 = .5 in.
   C_3 = .1 in.
   C_4 = .3 in.
   C_5 = .5 in.
   C_6 = .7 in.
   E_{2est} = 5330.1 (ft-lb_f)
   %Error= -16.9 %
   Vehicle #2 available, Vehicle #1 missing
   L = 30.5 in.
   C_1 = 8.9 in.
   C_2 = 9.2 in.
   C_3 = 8.0 in.
   C_4 = 7.0 in.
   C_5 = 5.6 in.
   C_6 = 4.6 in.
   E_{1est} = 13764.7 (ft-lb_f)
   %Error= 103.0 %

5. The proposed algorithm (equation (11.1)) is used with vehicle-specific values of d_0 and d_1 to obtain the estimates of energies absorbed. The estimated profile generation is not required for this calculation.

   Vehicle #1 available, Vehicle #2 missing
   From eqn. (11.1),

   $$E_2 = \frac{(d_1^2)_{veh1}}{(d_1^2)_{veh2}} \times E_1$$
   $$= \frac{6.45^2}{5.21^2} \times 6779.4$$
   $$= 10390.5 \quad (ft\text{-}lb_f)$$

   %Error = 62.0 %

   Vehicle #2 available, Vehicle #1 missing
   From eqn. (11.1),

$$\begin{aligned} E_1 &= \frac{(d_1^2)_{veh2}}{(d_1^2)_{veh1}} \times E_2 \\ &= \frac{5.21^2}{6.45^2} \times 6414.7 \\ &= 4185.35 \quad (ft\text{-}lb_f) \end{aligned}$$

%Error =-38.3 %

E.4 RICSAC TEST # 4

This test involves an offset oblique front-to-rear car-to-car impact of a 1974 Ford Torino (4980 lbs.) and a 1974 Ford Pinto (3190 lbs.) At impact, the bullet vehicle was travelling at 38.7 mph. The measured crushes and crush coeff. are:

Vehicle #1 '74 Torino (front impact):
Vehicle specific $d_0 = 61.54$ ($\sqrt{lb_f}$); $d_1 = 6.45$ ($\sqrt{lb_f}$/in) Ref [6]
Used in OLDMISS A = 355.9 ($1f_f$/in); B = 33.8 (lb_f/in^2) Ref [4]
Measured crushes:

L = 41.5 in.
C_1 = 6.3 in.
C_2 = 7.8 in.
C_3 = 9.8 in.
C_4 = 12.5 in.
C_5 = 14.8 in.
C_6 = 18.3 in.
D = 16.1 in.

Vehicle #2 '74 Pinto (rear impact):
Vehicle specific $d_0 = 44.26$ ($\sqrt{lb_f}$); $d_1 = 5.21$ ($\sqrt{lb_f}$/in) Ref [5]
Used in OLDMISS A = 390.5 ($1f_f$/in); B = 40.7 (lb_f/in^2) Ref [4]
Measured crushes:

L = 41.8 in.
C_1 = 36.0 in.
C_2 = 31.8 in.
C_3 = 29.0 in.
C_4 = 24.0 in.
C_5 = 19.5 in.
C_6 = 14.8 in.
D = -9.1 in.

1. Actual crush-energy absorbed by the two vehicles is calculated using equations (C.1) and vehicle specific values of d_0 and d_1 and actual measured crushes listed above. These are the values which would be generated by the CRASH3 program, if both vehicles are available for measurement. The values are:

   E_1 = 32529.4 ($ft\text{-}lb_f$)
   E_2 = 57749.7 ($ft\text{-}lb_f$)

2. The present OLDMISS results are obtained by running OLDMISS to obtain the predicted crushes and the absorbed energies. The predicted crushes and energies absorbed for the two possible cases are:

Vehicle #1 available, Vehicle #2 missing
L = 42.1 in.
C_1 = 4.0 in.
C_2 = 5.2 in.
C_3 = 6.8 in.
C_4 = 9.0 in.
C_5 = 10.8 in.
C_6 = 13.6 in.
E_{2est} = 23639.2 (ft-lb$_f$)
%Error= -59.1 %

Vehicle #2 available, Vehicle #1 missing
L = 42.4 in.
C_1 = 44.4 in.
C_2 = 39.3 in.
C_3 = 35.9 in.
C_4 = 29.9 in.
C_5 = 24.5 in.
C_6 = 18.8 in.
E_{1est} = 112668.8 (ft-lb$_f$)
%Error= 246.4 %

5. The proposed algorithm (equation (11.1)) is used with vehicle-specific values of d_0 and d_1 to obtain the estimates of energies absorbed. The estimated profile generation is not required for this calculation.

Vehicle #1 available, Vehicle #2 missing
From eqn. (11.1),

$$E_2=\frac{(d_1^2)_{veh1}}{(d_1^2)_{veh2}}\times E_1$$

$$=\frac{6.45^2}{5.21^2}\times 32529.4$$

$$=49856.3 \quad (ft\text{-}lb_f)$$

%Error =-13.7 %

Vehicle #2 available, Vehicle #1 missing
From eqn. (11.1),

$$E_1=\frac{(d_1^2)_{veh2}}{(d_1^2)_{veh1}}\times E_2$$

$$=\frac{5.21^2}{6.45^2}\times 57749.7$$

$$=37679.5 \quad (ft\text{-}lb_f)$$

%Error = 15.8 %

E.5 RICSAC TEST # 5

This test involves an offset oblique front-to-rear car-to-car impact of a 1974 Ford Torino (4600 lbs.) and a 1975 Honda Civic (2530 lbs.) At impact, the bullet vehicle was travelling at 39.8 mph. The measured crushes and crush coeff. are:

Vehicle #1 '74 Torino (front impact):
Vehicle specific d_0 = 61.54 ($\sqrt{lb_f}$); d_1 = 6.45 ($\sqrt{lb_f}$/in) Ref [6]
Used in OLDMISS A = 355.9 (lf$_f$/in); B = 33.8 (lb$_f$/in^2) Ref [4]
Measured crushes:

L = 33.4 in.
C_1 = 1.4 in.
C_2 = 1.4 in.
C_3 = 2.0 in.
C_4 = 2.1 in.
C_5 = 2.3 in.
C_6 = 2.9 in.
D = 20.3 in.

Vehicle #2 '75 Civic (rear impact):
Vehicle specific $d_0 = 43.10$ ($\sqrt{lb_f}$); $d_1 = 4.97$ ($\sqrt{lb_f}/in$) Ref [5]
Used in OLDMISS $A = 365.7$ (lf_f/in); $B = 38.1$ (lb_f/in^2) Ref [4]
Measured crushes:

L = 53.0 in.
C_1 = 36.0 in.
C_2 = 36.5 in.
C_3 = 31.5 in.
C_4 = 23.0 in.
C_5 = 13.3 in.
C_6 = 6.0 in.
D = -1.6 in.

1. Actual crush-energy absorbed by the two vehicles is calculated using equations (C.1) and vehicle specific values of d_0 and d_1 and actual measured crushes listed above. These are the values which would be generated by the CRASH3 program, if both vehicles are available for measurement. The values are:
   E_1 = 7732.0 (ft-lb_f)
   E_2 = 67691.8 (ft-lb_f)

2. The present OLDMISS results are obtained by running OLDMISS to obtain the predicted crushes and the absorbed energies. The predicted crushes and energies absorbed for the two possible cases are:

   Vehicle #1 available, Vehicle #2 missing
   L = 33.9 in.
   C_1 = .7 in.
   C_2 = .7 in.
   C_3 = 1.2 in.
   C_4 = 1.3 in.
   C_5 = 1.4 in.
   C_6 = 2.0 in.
   E_{2est} = 6447.5 (ft-lb_f)
   %Error= -90.4 %

   Vehicle #2 available, Vehicle #1 missing
   L = 53.8 in.
   C_1 = 40.9 in.
   C_2 = 41.4 in.
   C_3 = 35.8 in.
   C_4 = 26.2 in.
   C_5 = 15.3 in.
   C_6 = 7.1 in.
   E_{1est} = 125610.9 (ft-lb_f)
   %Error= 1524.6 %

5. The proposed algorithm (equation (11.1)) is used with vehicle-specific values of d_0 and d_1 to obtain the estimates of energies absorbed. The estimated profile generation is not required for this calculation.

Vehicle #1 available, Vehicle #2 missing
From eqn. (11.1),

$$E_2 = \frac{(d_1^2)_{veh1}}{(d_1^2)_{veh2}} \times E_1$$
$$= \frac{6.45^2}{4.97^2} \times 7732.0$$
$$= 13022.6 \quad (ft\text{-}lb_f)$$

%Error =-80.8 %

Vehicle #2 available, Vehicle #1 missing
From eqn. (11.1),

$$E_1 = \frac{(d_1^2)_{veh2}}{(d_1^2)_{veh1}} \times E_2$$
$$= \frac{4.97^2}{6.45^2} \times 67691.8$$
$$= 40191.0 \quad (ft\text{-}lb_f)$$

%Error = 419.8 %

E.6 RICSAC TEST # 6

This test involves an offset oblique front-to-side car-to-car impact of a 1974 Chevelle Malibu (4310 lbs.) and a 1975 Volkswagen Rabbit (2640 lbs.) At impact, each vehicle was travelling at 21.5 mph. The measured crushes and crush coeff. are:

Vehicle #1 '74 Chevelle (front impact):
Vehicle specific $d_0 = 59.80$ $(\sqrt{lb_f})$; $d_1 = 6.95$ $(\sqrt{lb_f}/in)$ Ref [6]
Used in OLDMISS $A = 355.9$ (lf_f/in); $B = 33.8$ (lb_f/in^2) Ref [4]
Measured crushes:

L = 54.5 in.
C_1 = .5 in.
C_2 = .5 in.
C_3 = 1.3 in.
C_4 = 1.5 in.
C_5 = 1.8 in.
C_6 = 2.3 in.
D = 9.8 in.

Vehicle #2 '75 Rabbit (side impact):
Vehicle specific $d_0 = 30.0$ $(\sqrt{lb_f})$; $d_1 = 7.60$ $(\sqrt{lb_f}/in)$ Ref [5]
Used in OLDMISS $A = 77.2$ (lf_f/in); $B = 36.7$ (lb_f/in^2) Ref [4]
Measured crushes:

L = 77.0 in.
C_1 = 4.0 in.
C_2 = 12.0 in.
C_3 = 17.9 in.
C_4 = 19.3 in.
C_5 = 17.0 in.
C_6 = 8.3 in.
D = -3.3 in.

1. Actual crush-energy absorbed by the two vehicles is calculated using equations (C.1) and vehicle specific values of d_0 and d_1 and actual measured crushes listed above. These are the values which would be generated by the

CRASH3 program, if both vehicles are available for measurement. The values are:

E_1 = 10738.4 (ft-lb_f)
E_2 = 66208.4 (ft-lb_f)

2. The present OLDMISS results are obtained by running OLDMISS to obtain the predicted crushes and the absorbed energies. The predicted crushes and energies absorbed for the two possible cases are:

Vehicle #1 available, Vehicle #2 missing

L = 48.4 in.
C_1 = 4.5 in.
C_2 = 4.5 in.
C_3 = 5.0 in.
C_4 = 5.1 in.
C_5 = 5.3 in.
C_6 = 5.6 in.
E_{2est} = 7454.5 (ft-lb_f)
%Error= -88.7 %

Vehicle #2 available, Vehicle #1 missing

L = 65.1 in.
C_1 = 32.0 in.
C_2 = 36.1 in.
C_3 = 35.2 in.
C_4 = 28.7 in.
C_5 = 17.3 in.
C_6 = 3.1 in.
E_{1est} = 183490.7 (ft-lb_f)
%Error= 1608.7 %

5. The proposed algorithm (equations (11.2) and (11.3)) is used with vehicle-specific values of d_0 and d_1 to obtain the estimates of energies absorbed. The estimated profile generation is not required for this calculation.

Vehicle #1 available, Vehicle #2 missing

From eqn. (11.2),

$$\begin{aligned} E_2 &= 2.1 \times \frac{(d_1^2)_{veh1}}{(d_1^2)_{veh2}} \times E_1 \\ &= 2.1 \times \frac{6.95^2}{7.60^2} \times 10738.4 \\ &= 18858.2 \quad (ft\text{-}lb_f) \end{aligned}$$

%Error =-71.5 %

Vehicle #2 available, Vehicle #1 missing

From eqn. (11.3),

$$\begin{aligned} E_1 &= \frac{(d_1^2)_{veh2}}{(d_1^2)_{veh1}} \times \frac{E_2}{2.1} \\ &= \frac{7.60^2}{6.95^2} \times \frac{66208.4}{2.1} \\ &= 37700.9 \quad (ft\text{-}lb_f) \end{aligned}$$

%Error = 251.1 %

E.7 RICSAC TEST # 7

This test involves an offset oblique front-to-side car-to-car impact of a 1974 Chevelle Malibu (4310 lbs.) and a 1975 Volkswagen Rabbit (2610 lbs.) At impact, each vehicle was travelling at 29.1 mph. The measured crushes and crush coeff. are:

Vehicle #1 '74 Chevelle (front impact):
Vehicle specific $d_0 = 59.80$ $(\sqrt{lb_f})$; $d_1 = 6.95$ $(\sqrt{lb_f}/in)$ Ref [6]
Used in OLDMISS $A = 355.9$ $(1f_f/in)$; $B = 33.8$ (lb_f/in^2) Ref [4]
Measured crushes:

L = 66.0 in.
C_1 = .0 in.
C_2 = 1.3 in.
C_3 = 2.0 in.
C_4 = 3.8 in.
C_5 = 5.0 in.
C_6 = 6.3 in.
D = 4.0 in.

Vehicle #2 '75 Rabbit (side impact):
Vehicle specific $d_0 = 30.0$ $(\sqrt{lb_f})$; $d_1 = 7.60$ $(\sqrt{lb_f}/in)$ Ref [5]
Used in OLDMISS $A = 77.2$ $(1f_f/in)$; $B = 36.7$ (lb_f/in^2) Ref [4]
Measured crushes:

L = 108.5 in.
C_1 = .5 in.
C_2 = 11.0 in.
C_3 = 17.8 in.
C_4 = 21.0 in.
C_5 = 21.3 in.
C_6 = 7.3 in.
D = -8.5 in.

1. Actual crush-energy absorbed by the two vehicles is calculated using equations (C.1) and vehicle specific values of d_0 and d_1 and actual measured crushes listed above. These are the values which would be generated by the CRASH3 program, if both vehicles are available for measurement. The values are:
   E_1 = 18416.4 (ft-lb_f)
   E_2 = 102551.1 (ft-lb_f)
2. The present OLDMISS results are obtained by running OLDMISS to obtain the predicted crushes and the absorbed energies. The predicted crushes and energies absorbed for the two possible cases are:
   Vehicle #1 available, Vehicle #2 missing
   L = 60.3 in.
   C_1 = 4.0 in.
   C_2 = 4.8 in.
   C_3 = 5.2 in.
   C_4 = 6.2 in.
   C_5 = 6.9 in.
   C_6 = 7.7 in.
   E_{2est} = 11736.3 (ft-lb_f)
   %Error= -88.6 %
   Vehicle #2 available, Vehicle #1 missing
   L = 77.0 in.
   C_1 = 51.5 in.
   C_2 = 50.9 in.
   C_3 = 47.1 in.
   C_4 = 39.9 in.
   C_5 = 27.1 in.
   C_6 = 8.9 in.
   E_{1est} = 377983.9 (ft-lb_f)
   %Error= 1952.4 %

5. The proposed algorithm (equations (11.2) and (11.3)) is used with vehicle-specific values of d_0 and d_1 to obtain the estimates of energies absorbed. The estimated profile generation is not required for this calculation.
   Vehicle #1 available, Vehicle #2 missing
   From eqn. (11.2),

$$
\begin{aligned}
E_2 &= 2.1 \times \frac{(d_1^2)_{veh1}}{(d_1^2)_{veh2}} \times E_1 \\
&= 2.1 \times \frac{6.95^2}{7.60^2} \times 18416.4 \\
&= 32342.0 \quad (ft\text{-}lb_f)
\end{aligned}
$$

   %Error =-68.5 %
   Vehicle #2 available, Vehicle #1 missing
   From eqn. (11.3),

$$
\begin{aligned}
E_1 &= \frac{(d_1^2)_{veh2}}{(d_1^2)_{veh1}} \times \frac{E_2}{2.1} \\
&= \frac{7.60^2}{6.95^2} \times \frac{102551.1}{2.1} \\
&= 58395.4 \quad (ft\text{-}lb_f)
\end{aligned}
$$

   %Error = 217.1 %

E.8 RICSAC TEST # 8

This test involves an offset perpendicular front-to-side car-to-car impact of two 1974 Chevelle Malibus (4480 lbs. and 4710 lbs.). At impact, each vehicle was travelling at 20.8 mph. The measured crushes and crush coeff. are:

Vehicle #1 '74 Chevelle (front impact):
Vehicle specific $d_0 = 59.80$ ($\sqrt{lb_f}$); $d_1 = 6.95$ ($\sqrt{lb_f}$/in) Ref [6]
Used in OLDMISS $A = 355.9$ (lf_f/in); $B = 33.8$ (lb_f/in^2) Ref [4]
Measured crushes:

L = 73.0 in.
C_1 = 2.7 in.
C_2 = 3.6 in.
C_3 = .0 in.
C_4 = .0 in.
C_5 = .0 in.
C_6 = .0 in.
D = .0 in.

Vehicle #2 '74 Chevelle (side impact):
Vehicle specific $d_0 = 30.00$ ($\sqrt{lb_f}$); $d_1 = 8.57$ ($\sqrt{lb_f}$/in) Ref [6]
Used in OLDMISS $A = 143.0$ (lf_f/in); $B = 50.4$ (lb_f/in^2) Ref [4]
Measured crushes:

L = 84.5 in.
C_1 = 6.2 in.
C_2 = 8.3 in.
C_3 = 9.2 in.
C_4 = 6.0 in.
C_5 = 4.4 in.
C_6 = .8 in.
D = 15.0 in.

1. Actual crush-energy absorbed by the two vehicles is calculated using equations (C.1) and vehicle specific values of d_0 and d_1 and actual measured

crushes listed above. These are the values which would be generated by the CRASH3 program, if both vehicles are available for measurement. The values are:

E_1 = 13800.6 (ft-lb_f)
E_2 = 25984.2 (ft-lb_f)

2. The present OLDMISS results are obtained by running OLDMISS to obtain the predicted crushes and the absorbed energies. The predicted crushes and energies absorbed for the two possible cases are:

Vehicle #1 available, Vehicle #2 missing

L = 73.0 in.
C_1 = 6.0 in.
C_2 = 6.6 in.
C_3 = 4.2 in.
C_4 = 4.2 in.
C_5 = 4.2 in.
C_6 = 4.2 in.
E_{2est} = 18552.6 (ft-lb_f)
%Error= -28.6 %

Vehicle #2 available, Vehicle #1 missing

L = 77.0 in.
C_1 = 4.3 in.
C_2 = 7.4 in.
C_3 = 8.9 in.
C_4 = 5.3 in.
C_5 = 2.2 in.
C_6 = .0 in.
E_{1est} = 55141.6 (ft-lb_f)
%Error= 299.6 %

5. The proposed algorithm (equations (11.2) and (11.3)) is used with vehicle-specific values of d_0 and d_1 to obtain the estimates of energies absorbed. The estimated profile generation is not required for this calculation.

Vehicle #1 available, Vehicle #2 missing

From eqn. (11.2),

$$E_2 = 2.1 \times \frac{(d_1^2)_{veh1}}{(d_1^2)_{veh2}} \times E_1$$
$$= 2.1 \times \frac{6.95^2}{8.57^2} \times 13800.6$$
$$= 19060.1 \quad (ft\text{-}lb_f)$$

%Error =-26.6 %

Vehicle #2 available, Vehicle #1 missing

From eqn. (11.3),

$$E_1 = \frac{(d_1^2)_{veh2}}{(d_1^2)_{veh1}} \times \frac{E_2}{2.1}$$
$$= \frac{8.57^2}{6.95^2} \times \frac{25984.2}{2.1}$$
$$= 18814.0 \quad (ft\text{-}lb_f)$$

%Error = 36.3 %

E.9 RICSAC TEST # 9

This test involves an offset perpendicular front-to-side car-to-car impact of a 1975 Honda Civic (2270 lbs) and a 1974 Ford Torino (4930 lbs). At impact, each vehicle was travelling at 21.3 mph. The measured crushes and crush coeff. are:

Vehicle #1 '75 Civic (front impact):
Vehicle specific $d_0 = 40.73$ ($\sqrt{lb_f}$); $d_1 = 7.09$ ($\sqrt{lb_f}$/in) Ref [6]
Used in OLDMISS $A = 373.4$ (lf_f/in); $B = 37.7$ (lb_f/in^2) Ref [4]
Measured crushes:

L = 49.8 in.
C_1 = 5.0 in.
C_2 = 5.8 in.
C_3 = 12.5 in.
C_4 = 7.5 in.
C_5 = 7.5 in.
C_6 = 9.5 in.
D = 1.6 in.

Vehicle #2 '74 Torino (side impact):
Vehicle specific $d_0 = 30.00$ ($\sqrt{lb_f}$); $d_1 = 8.50$ ($\sqrt{lb_f}$/in) Ref [6]
Used in OLDMISS $A = 143.0$ (lf_f/in); $B = 50.4$ (lb_f/in^2) Ref [4]
Measured crushes:

L = 54.5 in.
C_1 = 7.8 in.
C_2 = 4.6 in.
C_3 = 4.8 in.
C_4 = 3.3 in.
C_5 = 2.8 in.
C_6 = 1.5 in.
D = 68.0 in.

1. Actual crush-energy absorbed by the two vehicles is calculated using equations (C.1) and vehicle specific values of d_0 and d_1 and actual measured crushes listed above. These are the values which would be generated by the CRASH3 program, if both vehicles are available for measurement. The values are:

   E_1 = 20366.1 (ft-lb_f)
   E_2 = 9668.1 (ft-lb_f)

2. The present OLDMISS results are obtained by running OLDMISS to obtain the predicted crushes and the absorbed energies. The predicted crushes and energies absorbed for the two possible cases are:

   Vehicle #1 available, Vehicle #2 missing
   L = 49.8 in.
   C_1 = 8.3 in.
   C_2 = 8.9 in.
   C_3 = 14.0 in.
   C_4 = 10.2 in.
   C_5 = 10.2 in.
   C_6 = 11.7 in.
   E_{2est} = 38640.9 (ft-lb_f)
   %Error= 299.7 %

   Vehicle #2 available, Vehicle #1 missing
   L = 54.5 in.
   C_1 = 4.3 in.

C_2 = .0 in.
C_3 = .3 in.
C_4 = .0 in.
C_5 = .0 in.
C_6 = .0 in.
E_{1est} = 18539.5 (ft-lb_f)
%Error= -9.0 %

5. The proposed algorithm (equations (11.2) and (11.3)) is used with vehicle-specific values of d_0 and d_1 to obtain the estimates of energies absorbed. The estimated profile generation is not required for this calculation.

Vehicle #1 available, Vehicle #2 missing
From eqn. (11.2),

$$\begin{aligned} E_2 &= 2.1 \times \frac{(d_1^2)_{veh1}}{(d_1^2)_{veh2}} \times E_1 \\ &= 2.1 \times \frac{7.09^2}{8.50^2} \times 20366.1 \\ &= 29756.5 \quad (ft\text{-}lb_f) \end{aligned}$$

%Error =207.8 %

Vehicle #2 available, Vehicle #1 missing
From eqn. (11.3),

$$\begin{aligned} E_1 &= \frac{(d_1^2)_{veh2}}{(d_1^2)_{veh1}} \times \frac{E_2}{2.1} \\ &= \frac{8.50^2}{7.09^2} \times \frac{9668.5}{2.1} \\ &= 6617.4 \quad (ft\text{-}lb_f) \end{aligned}$$

%Error =-67.5 %

E.10 RICSAC TEST # 10

This test involves an offset perpendicular front-to-side car-to-car impact of a 1975 Honda Civic (2320 lbs) and a 1974 Ford Torino (4750 lbs). At impact, each vehicle was travelling at 33.4 mph. The measured crushes and crush coeff. are:

Vehicle #1 '75 Civic (front impact):
Vehicle specific $d_0 = 40.73$ ($\sqrt{lb_f}$); $d_1 = 7.09$ ($\sqrt{lb_f}$/in) Ref [6]
Used in OLDMISS A = 373.4 (lf_f/in); B = 37.7 (lb_f/in^2) Ref [4]
Measured crushes:

L = 47.5 in.
C_1 = 7.0 in.
C_2 = 10.2 in.
C_3 = 14.0 in.
C_4 = 8.9 in.
C_5 = 7.0 in.
C_6 = 9.0 in.
D = -2.8 in.

Vehicle #2 '74 Torino (side impact):
Vehicle specific $d_0 = 30.00$ ($\sqrt{lb_f}$); $d_1 = 8.50$ ($\sqrt{lb_f}$/in) Ref [6]
Used in OLDMISS A = 143.0 (lf_f/in); B = 50.4 (lb_f/in^2) Ref [4]
Measured crushes:

L = 53.0 in.
C_1 = 9.2 in.
C_2 = 6.5 in.
C_3 = 6.1 in.
C_4 = 5.3 in.
C_5 = 4.5 in.
C_6 = .5 in.
D = 66.5 in.

1. Actual crush-energy absorbed by the two vehicles is calculated using equations (C.1) and vehicle specific values of d_0 and d_1 and actual measured crushes listed above. These are the values which would be generated by the CRASH3 program, if both vehicles are available for measurement. The values are:

   E_1 = 23900.9 (ft-lb$_f$)
   E_2 = 12803.9 (ft-lb$_f$)

2. The present OLDMISS results are obtained by running OLDMISS to obtain the predicted crushes and the absorbed energies. The predicted crushes and energies absorbed for the two possible cases are:

   Vehicle #1 available, Vehicle #2 missing
   L = 47.5 in.
   C_1 = 9.8 in.
   C_2 = 12.3 in.
   C_3 = 15.1 in.
   C_4 = 11.3 in.
   C_5 = 9.8 in.
   C_6 = 11.3 in.
   E_{2est} = 43299.6 (ft-lb$_f$)
   %Error= 238.1 %

   Vehicle #2 available, Vehicle #1 missing
   L = 53.0 in.
   C_1 = 6.1 in.
   C_2 = 2.6 in.
   C_3 = 2.0 in.
   C_4 = 1.0 in.
   C_5 = .0 in.
   C_6 = .0 in.
   E_{1est} = 22811.8 (ft-lb$_f$)
   %Error= -4.6 %

5. The proposed algorithm (equations (11.2) and (11.3)) is used with vehicle-specific values of d_0 and d_1 to obtain the estimates of energies absorbed. The estimated profile generation is not required for this calculation.

   Vehicle #1 available, Vehicle #2 missing
   From eqn. (11.2),

$$
\begin{aligned}
E_2 &= 2.1\times\frac{(d_1^2)_{veh1}}{(d_1^2)_{veh2}}\times E_1\\
&= 2.1\times\frac{7.09^2}{8.50^2}\times 23900.9\\
&= 34921.1 \quad (ft\text{-}lb_f)
\end{aligned}
$$

%Error =172.7 %

Vehicle #2 available, Vehicle #1 missing
From eqn. (11.3),

$$E_1=\frac{(d_1^2)_{veh2}}{(d_1^2)_{veh1}}\times\frac{E_2}{2.1}$$

$$=\frac{8.50^2}{7.09^2}\times\frac{12803.9}{2.1}$$

$$=8763.3 \quad (ft\text{-}lb_f)$$

%Error =-63.3 %

E.11 RICSAC TEST # 11

This test involves an offset oblique front-to-front car-to-car impact of a 1974 Chevrolet Vega (3060 lbs.) and a 1974 Ford Torino (4880 lbs.) At impact, the vehicles were travelling at 20.4 mph. The measured crushes and crush coeff. are:

Vehicle #1 '74 Vega (front impact):
Vehicle specific $d_0 = 42.83$ $(\sqrt{lb_f})$; $d_1 = 7.68$ $(\sqrt{lb_f}/in)$ Ref [6]
Used in OLDMISS $A = 259.4$ (lf$_f$/in); $B = 43.2$ (lb$_f$/in^2) Ref [4]
Measured crushes:

L = 32.5 in.
C_1 = 22.0 in.
C_2 = 20.2 in.
C_3 = 18.5 in.
C_4 = 16.8 in.
C_5 = 15.0 in.
C_6 = 12.5 in.
D = 12.8 in.

Vehicle #2 '74 Torino (front impact):
Vehicle specific $d_0 = 61.54$ $(\sqrt{lb_f})$; $d_1 = 6.45$ $(\sqrt{lb_f}/in)$ Ref [5]
Used in OLDMISS $A = 355.9$ (lf$_f$/in); $B = 33.8$ (lb$_f$/in^2) Ref [4]
Measured crushes:

L = 33.3 in.
C_1 = 29.2 in.
C_2 = 26.3 in.
C_3 = 23.0 in.
C_4 = 18.7 in.
C_5 = 14.2 in.
C_6 = 11.0 in.
D = 12.9 in.

1. Actual crush-energy absorbed by the two vehicles is calculated using equations (C.1) and vehicle specific values of d_0 and d_1 and actual measured crushes listed above. These are the values which would be generated by the CRASH3 program, if both vehicles are available for measurement. The values are:
   E_1 = 43305.9 (ft-lb$_f$)
   E_2 = 52199.8 (ft-lb$_f$)

2. The present OLDMISS results are obtained by running OLDMISS to obtain the predicted crushes and the absorbed energies. The predicted crushes and energies absorbed for the two possible cases are:

   Vehicle #1 available, Vehicle #2 missing
   L = 32.0 in.
   C_1 = 13.5 in.

C_2 = 16.7 in.
C_3 = 19.1 in.
C_4 = 21.3 in.
C_5 = 23.5 in.
C_6 = 25.8 in.
E_{2est} = 42978.8 (ft-lb_f)
%Error= -17.6 %

Vehicle #2 available, Vehicle #1 missing

L = 33.8 in.
C_1 = 10.6 in.
C_2 = 13.1 in.
C_3 = 16.5 in.
C_4 = 19.8 in.
C_5 = 22.4 in.
C_6 = 24.6 in.
E_{1est} = 36096.8 (ft-lb_f)
%Error= -16.6 %

5. The proposed algorithm (equation (11.1)) is used with vehicle-specific values of d_0 and d_1 to obtain the estimates of energies absorbed. The estimated profile generation is not required for this calculation.

Vehicle #1 available, Vehicle #2 missing
From eqn. (11.1),

$$E_2=\frac{(d_1^2)_{veh1}}{(d_1^2)_{veh2}}\times E_1$$
$$=\frac{7.68^2}{6.45^2}\times 43305.9$$
$$=61397.4\ \ (ft\text{-}lb_f)$$

%Error = 17.6 %

Vehicle #2 available, Vehicle #1 missing
From eqn. (11.1),

$$E_1=\frac{(d_1^2)_{veh2}}{(d_1^2)_{veh1}}\times E_2$$
$$=\frac{6.45^2}{7.68^2}\times 52199.8$$
$$=36818.5\ \ (ft\text{-}lb_f)$$

%Error =-15.0 %

E.12 RICSAC TEST # 12

This test involves an offset oblique front-to-front car-to-car impact of a 1974 Chevrolet Vega (3150 lbs.) and a 1974 Ford Torino (4540 lbs.) At impact, the vehicles were travelling at 31.5 mph. The measured crushes and crush coeff. are:

Vehicle #1 '74 Vega (front impact):
Vehicle specific d_0 = 42.83 ($\sqrt{lb_f}$); d_1 = 7.68 ($\sqrt{lb_f}$/in) Ref [6]
Used in OLDMISS A = 259.4 (lf_f/in); B = 43.2 (lb_f/in^2) Ref [4]
Measured crushes:

L = 32.0 in.
C_1 = 38.6 in.
C_2 = 34.6 in.
C_3 = 29.5 in.

C_4 = 26.0 in.
C_5 = 19.6 in.
C_6 = 14.3 in.
D = in.

Vehicle #2 '74 Torino (front impact):
Vehicle specific $d_0 = 61.54$ $(\sqrt{\mathrm{lb}_f})$; $d_1 = 6.45$ $(\sqrt{\mathrm{lb}_f}/\mathrm{in})$ Ref [5]
Used in OLDMISS $A = 355.9$ $(\mathrm{lf}_f/\mathrm{in})$; $B = 33.8$ $(\mathrm{lb}_f/\mathrm{in}^2)$ Ref [4]
Measured crushes:

L = 28.3 in.
C_1 = 39.5 in.
C_2 = 33.0 in.
C_3 = 28.8 in.
C_4 = 23.8 in.
C_5 = 19.2 in.
C_6 = 15.3 in.
D = 10.6 in.

1. Actual crush-energy absorbed by the two vehicles is calculated using equations (C.1) and vehicle specific values of d_0 and d_1 and actual measured crushes listed above. These are the values which would be generated by the CRASH3 program, if both vehicles are available for measurement. The values are:

   E_1 = 88586.0 $(\mathrm{ft\text{-}lb}_f)$
   E_2 = 65630.5 $(\mathrm{ft\text{-}lb}_f)$

2. The present OLDMISS results are obtained by running OLDMISS to obtain the predicted crushes and the absorbed energies. The predicted crushes and energies absorbed for the two possible cases are:

   Vehicle #1 available, Vehicle #2 missing
   L = 32.5 in.
   C_1 = 15.0 in.
   C_2 = 21.7 in.
   C_3 = 29.7 in.
   C_4 = 34.2 in.
   C_5 = 40.6 in.
   C_6 = 45.6 in.
   E_{2est} = 84291.3 $(\mathrm{ft\text{-}lb}_f)$
   %Error= 28.4 %

   Vehicle #2 available, Vehicle #1 missing
   L = 28.7 in.
   C_1 = 13.9 in.
   C_2 = 16.9 in.
   C_3 = 20.4 in.
   C_4 = 24.3 in.
   C_5 = 27.5 in.
   C_6 = 32.5 in.
   E_{1est} = 43753.6 $(\mathrm{ft\text{-}lb}_f)$
   %Error= -50.6 %

5. The proposed algorithm (equation (11.1)) is used with vehicle-specific values of d_0 and d_1 to obtain the estimates of energies absorbed. The estimated profile generation is not required for this calculation.

Vehicle #1 available, Vehicle #2 missing
From eqn. (11.1),

$$E_2=\frac{(d_1^2)_{veh1}}{(d_1^2)_{veh2}}\times E_1$$
$$=\frac{7.68^2}{6.45^2}\times 88586.0$$
$$=125593.8 \quad (ft\text{-}lb_f)$$

%Error = 91.3 %

Vehicle #2 available, Vehicle #1 missing
From eqn. (11.1),

$$E_1=\frac{(d_1^2)_{veh2}}{(d_1^2)_{veh1}}\times E_2$$
$$=\frac{6.45^2}{7.68^2}\times 65630.5$$
$$=46291.7 \quad (ft\text{-}lb_f)$$

%Error =-47.8 %

E.13 OLDMISS Output for RICSAC Reconstructions

The following are the output files for the RICSAC reconstructions. Each of the twelve RICSAC tests are reconstructed with vehicle 1 missing, 2 available, and with vehicle 2 missing, 1 available.

```
      SUMMARY OF OLDMISPC RESULTS

 RICSAC Test # 1; Vehicle 1 available; Vehicle 2 missing

                                             SPEED CHANGE (DAMAGE)

                               RESULTANT        LONGITUDINAL        LATERAL          PDOF
                               MPH   (KPH)      MPH     (KPH)     MPH     (KPH)      DEG

 VEH #1 (KNOWN)              9.70 ( 15.61)   -8.40 (-13.52)    4.85 (  7.80)   330.00
 VEH #2 (ESTIMATED)         14.50 ( 23.33)  -12.56 (-20.20)   -7.25 (-11.67)    30.00


                                     ENERGY                          FORCE
                                 FT-LBS    (NT-M)                  LBS       (NT)

 VEH #1 (KNOWN)                 33305.6   ( 45151.9)             34772.8  (154669.3)
 VEH #2 (ESTIMATED)              8223.2   ( 11148.0)             34772.8  (154669.3)
1
                                   SUMMARY OF DAMAGE DATA

                  VEHICLE #1                                 VEHICLE #2
           (KNOWN DAMAGE DIMENSION)                (ESTIMATED DAMAGE DIMENSION)
                          IN       (CM)                              IN       (CM)

 L-----------        46.0     116.8            L-----------      47.2     120.0
 C1----------         4.0      10.2            C1----------       2.0       5.2
 C2----------         5.5      14.0            C2----------       2.5       6.3
 C3----------         7.0      17.8            C3----------       2.9       7.3
 C4----------        10.2      25.9            C4----------       3.8       9.7
 C5----------        12.1      30.7            C5----------       4.3      11.0
 C6----------        14.8      37.6            C6----------       5.1      13.0
 D-----------        14.3      36.3            D-----------        .0        .0

                                       VEHICLE INFORMATION

                     VEHICLE #1                                 VEHICLE #2
               (FRONT DAMAGE KNOWN)                       (SIDE DAMAGE UNKNOWN)


 SIZE------          4                          SIZE------          2
 STIFFNESS-          4                          STIFFNESS-          2
 SIDE------          F                          SIDE------          R
 HANGL-----         .0 DEG                      HANGL-----     120.0 DEG
 WEIGHT----     4650.0 LBS (2108.8 KG)          WEIGHT----    3110.0 LBS (1410.4 KG)
 MASS------       12.034 LB-SEC**2/IN           MASS------        8.049 LB-SEC**2/IN
             ( 135.96 NT-SEC**2/CM)                         (   90.93 NT-SEC**2/CM)
 RADIUS                                         RADIUS
 GYRATION--   3741.0 IN**2                      GYRATION--   2951.0 IN**2
          ( 24135.4 CM**2)                               ( 19038.7 CM**2)
```

RICSAC Test # 1; Vehicle 1 available; Vehicle 2 missing

```
      SUMMARY OF OLDMISPC RESULTS

RICSAC Test # 1; Vehicle 2 available; Vehicle 1 missing
                                                SPEED CHANGE (DAMAGE)

                      RESULTANT        LONGITUDINAL        LATERAL          PDOF
                      MPH   (KPH)      MPH    (KPH)      MPH    (KPH)       DEG

VEH #1 (ESTIMATED)   39.95 ( 64.28)  -34.60 (-55.67)   19.97 ( 32.14)    -30.00
VEH #2 (KNOWN)       59.74 ( 96.11)  -51.73 (-83.23)  -29.88 (-48.07)     30.00


                           ENERGY                           FORCE
                        FT-LBS     (NT-M)                 LBS       (NT)

VEH #1 (ESTIMATED)     558360.8  (756960.8)            174523.8  (776281.9)
VEH #2 (KNOWN)          84609.4  (114703.6)            169900.5  (755717.2)
1
                                      SUMMARY OF DAMAGE DATA

            VEHICLE #1                                    VEHICLE #2
     (ESTIMATED DAMAGE DIMENSION)                  (KNOWN DAMAGE DIMENSION)
                          IN       (CM)                               IN       (CM)

L-----------        71.8    182.5              L-----------     113.3    287.8
C1----------        64.4    163.6              C1----------        .5      1.3
C2----------        60.5    153.7              C2----------      12.0     30.5
C3----------        59.4    151.0              C3----------      10.6     26.9
C4----------        64.0    162.5              C4----------      11.8     30.0
C5----------        40.7    103.4              C5----------       9.0     22.9
C6----------         3.5      8.9              C6----------       4.1     10.4
D-----------          .0       .0              D-----------      21.8     55.4

                                         VEHICLE INFORMATION

               VEHICLE #1                                    VEHICLE #2
          (FRONT DAMAGE UNKNOWN)                        (SIDE DAMAGE KNOWN)


SIZE------        4                           SIZE------        2
STIFFNESS-        4                           STIFFNESS-        2
SIDE------        F                           SIDE------        R
HANGL-----       .0 DEG                       HANGL-----    120.0 DEG
WEIGHT----   4650.0 LBS (2108.8 KG)           WEIGHT----   3110.0 LBS (1410.4 KG)
MASS------     12.034 LB-SEC**2/IN            MASS------      8.049 LB-SEC**2/IN
            ( 135.96 NT-SEC**2/CM)                       (  90.93 NT-SEC**2/CM)
RADIUS                                        RADIUS
GYRATION--  3741.0 IN**2                      GYRATION--  2951.0 IN**2
         ( 24135.4 CM**2)                              ( 19038.7 CM**2)
```

RICSAC Test # 1; Vehicle 2 available; Vehicle 1 missing

```
       SUMMARY OF OLDMISPC RESULTS

 RICSAC Test # 2; Vehicle 1 available; Vehicle 2 missing

                                    SPEED CHANGE (DAMAGE)

                       RESULTANT       LONGITUDINAL       LATERAL          PDOF
                       MPH   (KPH)     MPH     (KPH)    MPH     (KPH)      DEG

 VEH #1 (KNOWN)        11.58 ( 18.63)  -10.03 (-16.13)     5.79 (  9.31)   330.00
 VEH #2 (ESTIMATED)    16.73 ( 26.92)  -14.49 (-23.31)    -8.37 (-13.46)    30.00

                             ENERGY                          FORCE
                         FT-LBS    (NT-M)                 LBS      (NT)

 VEH #1 (KNOWN)          45272.7  ( 61375.5)             50767.2  (225812.5)
 VEH #2 (ESTIMATED)      11769.1  ( 15955.2)             50767.2  (225812.5)
1
                           SUMMARY OF DAMAGE DATA

             VEHICLE #1                           VEHICLE #2
    (KNOWN DAMAGE DIMENSION)              (ESTIMATED DAMAGE DIMENSION)
                  IN      (CM)                            IN      (CM)

 L-----------    75.5    191.8          L-----------     73.6    187.0
 C1----------      .5      1.3          C1----------      1.2      3.1
 C2----------     2.4      6.1          C2----------      1.8      4.5
 C3----------     3.7      9.4          C3----------      2.2      5.5
 C4----------     6.9     17.5          C4----------      3.1      7.9
 C5----------    12.0     30.5          C5----------      4.7     11.8
 C6----------    16.5     41.9          C6----------      6.0     15.3
 D-----------      .0       .0          D-----------       .0       .0

                               VEHICLE INFORMATION

                VEHICLE #1                           VEHICLE #2
          (FRONT DAMAGE KNOWN)                  (SIDE DAMAGE UNKNOWN)


 SIZE------       4                      SIZE------        2
 STIFFNESS-       4                      STIFFNESS-        2
 SIDE------       F                      SIDE------        R
 HANGL-----      .0 DEG                  HANGL-----    120.0 DEG
 WEIGHT----  4710.0 LBS (2136.1 KG)      WEIGHT----   3260.0 LBS (1478.5 KG)
 MASS------    12.189 LB-SEC**2/IN       MASS------       8.437 LB-SEC**2/IN
            ( 137.72 NT-SEC**2/CM)                   (  95.32 NT-SEC**2/CM)
 RADIUS                                  RADIUS
 GYRATION--  3741.0 IN**2                GYRATION--   2951.0 IN**2
          ( 24135.4 CM**2)                          ( 19038.7 CM**2)
```

RICSAC Test # 2; Vehicle 1 available; Vehicle 2 missing

```
       SUMMARY OF OLDMISPC RESULTS

 RICSAC Test # 2; Vehicle 2 available; Vehicle 1 missing

                                     SPEED CHANGE (DAMAGE)

                       RESULTANT        LONGITUDINAL       LATERAL         PDOF
                       MPH  (KPH)       MPH    (KPH)     MPH    (KPH)      DEG

 VEH #1 (ESTIMATED)   76.79 (123.55)   -66.50  (******)  38.39  ( 61.76)  -30.00
 VEH #2 (KNOWN)      110.94 (178.50)   -96.07  (******) -55.49  (-89.28)   30.00


                              ENERGY                         FORCE
                          FT-LBS    (NT-M)                LBS      (NT)

 VEH #1 (ESTIMATED)   2159652.0   (********)           347322.1  (********)
 VEH #2 (KNOWN)        254316.5   (344772.8)           289263.8  (********)
1
                            SUMMARY OF DAMAGE DATA

             VEHICLE #1                            VEHICLE #2
    (ESTIMATED DAMAGE DIMENSION)           (KNOWN DAMAGE DIMENSION)
                  IN      (CM)                            IN      (CM)

 L-----------    71.8    182.5           L-----------   118.5    301.0
 C1----------   121.4    308.3           C1----------     6.8     17.3
 C2----------   128.8    327.2           C2----------    22.8     57.9
 C3----------   133.0    337.8           C3----------    23.5     59.7
 C4----------   130.6    331.8           C4----------    21.3     54.1
 C5----------    93.8    238.2           C5----------    10.0     25.4
 C6----------    39.7    100.7           C6----------      .0       .0
 D-----------      .0       .0           D-----------    13.7     34.8

                                VEHICLE INFORMATION

                VEHICLE #1                            VEHICLE #2
          (FRONT DAMAGE UNKNOWN)                (SIDE DAMAGE KNOWN)


 SIZE------        4                      SIZE------        2
 STIFFNESS-        4                      STIFFNESS-        2
 SIDE------        F                      SIDE------        R
 HANGL-----      .0 DEG                   HANGL-----   120.0 DEG
 WEIGHT----  4710.0 LBS (2136.1 KG)       WEIGHT----  3260.0 LBS (1478.5 KG)
 MASS------    12.189 LB-SEC**2/IN        MASS------     8.437 LB-SEC**2/IN
            ( 137.72 NT-SEC**2/CM)                   (  95.32 NT-SEC**2/CM)
 RADIUS                                   RADIUS
 GYRATION--  3741.0 IN**2                 GYRATION--  2951.0 IN**2
          ( 24135.4 CM**2)                         ( 19038.7 CM**2)
```

RICSAC Test # 2; Vehicle 2 available; Vehicle 1 missing

```
      SUMMARY OF OLDMISPC RESULTS

  RICSAC Test # 3; Vehicle 1 available; Vehicle 2 missing

                                         SPEED CHANGE (DAMAGE)

                          RESULTANT        LONGITUDINAL       LATERAL          PDOF
                          MPH   (KPH)      MPH    (KPH)      MPH    (KPH)      DEG

  VEH #1 (KNOWN)          5.12 (  8.23)   -5.12 ( -8.23)     .00 (    .00)      .00
  VEH #2 (ESTIMATED)      8.12 ( 13.06)    7.99 ( 12.86)   -1.41 ( -2.27)   170.00


                                ENERGY                          FORCE
                            FT-LBS    (NT-M)                 LBS       (NT)

  VEH #1 (KNOWN)            6518.6  (  8837.1)             12593.5  ( 56015.7)
  VEH #2 (ESTIMATED)        5330.1  (  7226.0)             12593.5  ( 56015.7)
 1
                                SUMMARY OF DAMAGE DATA

                VEHICLE #1                           VEHICLE #2
     (KNOWN DAMAGE DIMENSION)             (ESTIMATED DAMAGE DIMENSION)
                     IN       (CM)                           IN       (CM)

  L-----------     30.0      76.2          L-----------     30.5      77.4
  C1----------      2.0       5.1          C1----------       .5       1.3
  C2----------      2.0       5.1          C2----------       .5       1.3
  C3----------      1.5       3.8          C3----------       .1        .2
  C4----------      1.8       4.6          C4----------       .3        .8
  C5----------      2.0       5.1          C5----------       .5       1.3
  C6----------      2.3       5.8          C6----------       .7       1.9
  D-----------     22.0      55.9          D-----------       .0        .0

                                    VEHICLE INFORMATION

                  VEHICLE #1                           VEHICLE #2
           (FRONT DAMAGE KNOWN)                 (REAR DAMAGE UNKNOWN)


  SIZE------        4                     SIZE------        2
  STIFFNESS-        4                     STIFFNESS-        2
  SIDE------        F                     SIDE------        B
  HANGL-----       .0 DEG                 HANGL-----     10.0 DEG
  WEIGHT----   4980.0 LBS (2258.5 KG)     WEIGHT----   3140.0 LBS (1424.0 KG)
  MASS------     12.888 LB-SEC**2/IN      MASS------      8.126 LB-SEC**2/IN
             ( 145.61 NT-SEC**2/CM)                 (  91.81 NT-SEC**2/CM)
  RADIUS                                  RADIUS
  GYRATION--  3741.0 IN**2                GYRATION--  2951.0 IN**2
           ( 24135.4 CM**2)                        ( 19038.7 CM**2)
```

RICSAC Test # 3; Vehicle 1 available; Vehicle 2 missing

```
     SUMMARY OF OLDMISPC RESULTS

RICSAC Test # 3; Vehicle 2 available; Vehicle 1 missing

                                          SPEED CHANGE (DAMAGE)

                          RESULTANT        LONGITUDINAL       LATERAL          PDOF
                          MPH   (KPH)      MPH    (KPH)     MPH    (KPH)       DEG

VEH #1 (ESTIMATED)     7.65 ( 12.31)    -7.65 (-12.31)      .00 (    .00)      .00
VEH #2 (KNOWN)        12.14 ( 19.53)    11.95 ( 19.23)    -2.11 ( -3.39)   170.00


                                 ENERGY                         FORCE
                            FT-LBS    (NT-M)                LBS        (NT)

VEH #1 (ESTIMATED)        13764.7   ( 18660.5)           18380.0   ( 81754.0)
VEH #2 (KNOWN)            11607.4   ( 15735.9)           18380.0   ( 81754.0)
1

                               SUMMARY OF DAMAGE DATA

            VEHICLE #1                                 VEHICLE #2
   (ESTIMATED DAMAGE DIMENSION)              (KNOWN DAMAGE DIMENSION)
                 IN       (CM)                               IN       (CM)

L-----------    30.5      77.4           L-----------    30.0      76.2
C1----------     8.9      22.5           C1----------     6.5      16.5
C2----------     9.2      23.4           C2----------     6.8      17.3
C3----------     8.0      20.3           C3----------     5.8      14.7
C4----------     7.0      17.9           C4----------     5.0      12.7
C5----------     5.6      14.2           C5----------     3.8       9.7
C6----------     4.6      11.8           C6----------     3.0       7.6
D-----------      .0        .0           D-----------    -5.0     -12.7

                                  VEHICLE INFORMATION

               VEHICLE #1                                  VEHICLE #2
        (FRONT DAMAGE UNKNOWN)                      (REAR DAMAGE KNOWN)


SIZE------        4                     SIZE------         2
STIFFNESS-        4                     STIFFNESS-         2
SIDE------        F                     SIDE------         B
HANGL-----       .0 DEG                 HANGL-----      10.0 DEG
WEIGHT----  4980.0 LBS (2258.5 KG)      WEIGHT----  3140.0 LBS (1424.0 KG)
MASS------     12.888 LB-SEC**2/IN      MASS------     8.126 LB-SEC**2/IN
           ( 145.61 NT-SEC**2/CM)                  (  91.81 NT-SEC**2/CM)
RADIUS                                  RADIUS
GYRATION--  3741.0 IN**2                GYRATION--  2951.0 IN**2
         ( 24135.4 CM**2)                        ( 19038.7 CM**2)
```

RICSAC Test # 3; Vehicle 2 available; Vehicle 1 missing

```
      SUMMARY OF OLDMISPC RESULTS

RICSAC Test # 4; Vehicle 1 available; Vehicle 2 missing

                                          SPEED CHANGE (DAMAGE)

                             RESULTANT        LONGITUDINAL        LATERAL          PDOF
                             MPH   (KPH)      MPH    (KPH)      MPH    (KPH)       DEG

VEH #1 (KNOWN)             10.88 ( 17.50)  -10.88 (-17.50)      .00 (    .00)       .00
VEH #2 (ESTIMATED)         16.98 ( 27.32)   16.72 ( 26.90)    -2.95 ( -4.74)    170.00


                                 ENERGY                            FORCE
                               FT-LBS    (NT-M)                  LBS       (NT)

VEH #1 (KNOWN)               28909.9  ( 39192.8)              30816.7  (137072.8)
VEH #2 (ESTIMATED)           23639.2  ( 32047.3)              30816.7  (137072.8)
1
                                 SUMMARY OF DAMAGE DATA

             VEHICLE #1                                 VEHICLE #2
     (KNOWN DAMAGE DIMENSION)                 (ESTIMATED DAMAGE DIMENSION)
                     IN      (CM)                               IN       (CM)

L-----------     41.5    105.4            L-----------     42.1     107.1
C1----------      6.3     16.0            C1----------      4.0      10.1
C2----------      7.8     19.8            C2----------      5.2      13.1
C3----------      9.8     24.9            C3----------      6.8      17.2
C4----------     12.5     31.8            C4----------      9.0      22.7
C5----------     14.8     37.6            C5----------     10.8      27.4
C6----------     18.3     46.5            C6----------     13.6      34.6
D-----------     16.1     40.9            D-----------       .0        .0

                                     VEHICLE INFORMATION

                VEHICLE #1                                  VEHICLE #2
          (FRONT DAMAGE KNOWN)                        (REAR DAMAGE UNKNOWN)


SIZE------        4                      SIZE------        2
STIFFNESS-        4                      STIFFNESS-        2
SIDE------        F                      SIDE------        B
HANGL-----       .0 DEG                  HANGL-----     10.0 DEG
WEIGHT----   4980.0 LBS (2258.5 KG)      WEIGHT----   3190.0 LBS (1446.7 KG)
MASS------     12.888 LB-SEC**2/IN       MASS------      8.256 LB-SEC**2/IN
            ( 145.61 NT-SEC**2/CM)                  (  93.27 NT-SEC**2/CM)
RADIUS                                   RADIUS
GYRATION--  3741.0 IN**2                 GYRATION--  2951.0 IN**2
         ( 24135.4 CM**2)                         ( 19038.7 CM**2)
```

RICSAC Test # 4; Vehicle 1 available; Vehicle 2 missing

```
      SUMMARY OF OLDMISPC RESULTS

RICSAC Test # 4; Vehicle 2 available; Vehicle 1 missing

                                   SPEED CHANGE (DAMAGE)

                      RESULTANT       LONGITUDINAL       LATERAL         PDOF
                      MPH   (KPH)     MPH    (KPH)     MPH    (KPH)      DEG

VEH #1 (ESTIMATED)   21.86 ( 35.17)  -21.86 (-35.17)    ..00 (   .00)      .00
VEH #2 (KNOWN)       34.13 ( 54.91)   33.61 ( 54.07)   -5.92 ( -9.53)   170.00


                            ENERGY                         FORCE
                        FT-LBS    (NT-M)                LBS      (NT)

VEH #1 (ESTIMATED)    112668.8  (152743.3)            61385.8  (273044.1)
VEH #2 (KNOWN)         95010.6  (128804.4)            61385.8  (273044.1)
1
                          SUMMARY OF DAMAGE DATA

            VEHICLE #1                           VEHICLE #2
   (ESTIMATED DAMAGE DIMENSION)          (KNOWN DAMAGE DIMENSION)
                 IN      (CM)                           IN      (CM)

L-----------    42.4    107.8          L-----------    41.8    106.2
C1----------    44.4    112.7          C1----------    36.0     91.4
C2----------    39.3     99.9          C2----------    31.8     80.8
C3----------    35.9     91.3          C3----------    29.0     73.7
C4----------    29.9     76.0          C4----------    24.0     61.0
C5----------    24.5     62.2          C5----------    19.5     49.5
C6----------    18.8     47.9          C6----------    14.8     37.6
D-----------      .0       .0          D-----------    -9.1    -23.1

                              VEHICLE INFORMATION

               VEHICLE #1                           VEHICLE #2
         (FRONT DAMAGE UNKNOWN)               (REAR DAMAGE KNOWN)


SIZE------       4                      SIZE------       2
STIFFNESS-       4                      STIFFNESS-       2
SIDE------       F                      SIDE------       B
HANGL-----      .0 DEG                  HANGL-----    10.0 DEG
WEIGHT----  4980.0 LBS (2258.5 KG)      WEIGHT----  3190.0 LBS (1446.7 KG)
MASS------    12.888 LB-SEC**2/IN       MASS------     8.256 LB-SEC**2/IN
           ( 145.61 NT-SEC**2/CM)                  (  93.27 NT-SEC**2/CM)
RADIUS                                  RADIUS
GYRATION--  3741.0 IN**2                GYRATION--  2951.0 IN**2
         ( 24135.4 CM**2)                        ( 19038.7 CM**2)
```

RICSAC Test # 4; Vehicle 2 available; Vehicle 1 missing

```
      SUMMARY OF OLDMISPC RESULTS

RICSAC Test # 5; Vehicle 1 available; Vehicle 2 missing

                                   SPEED CHANGE (DAMAGE)

                      RESULTANT        LONGITUDINAL       LATERAL         PDOF
                      MPH   (KPH)      MPH    (KPH)     MPH    (KPH)      DEG

VEH #1 (KNOWN)         5.52 (  8.88)   -5.52 ( -8.88)     .00 (   .00)      .00
VEH #2 (ESTIMATED)    10.03 ( 16.14)    9.88 ( 15.90)   -1.74 ( -2.80)   170.00

                           ENERGY                        FORCE
                        FT-LBS    (NT-M)              LBS       (NT)

VEH #1 (KNOWN)          7381.4  ( 10006.9)          14133.6  ( 62866.3)
VEH #2 (ESTIMATED)      6447.5  (  8740.8)          14133.6  ( 62866.3)
1
                              SUMMARY OF DAMAGE DATA

             VEHICLE #1                           VEHICLE #2
   (KNOWN DAMAGE DIMENSION)              (ESTIMATED DAMAGE DIMENSION)
                 IN       (CM)                           IN       (CM)

L-----------    33.4     84.8          L-----------    33.9      86.2
C1----------     1.4      3.6          C1----------      .7       1.7
C2----------     1.4      3.6          C2----------      .7       1.7
C3----------     2.0      5.1          C3----------     1.2       3.0
C4----------     2.1      5.3          C4----------     1.3       3.2
C5----------     2.3      5.8          C5----------     1.4       3.7
C6----------     2.9      7.4          C6----------     2.0       5.0
D-----------    20.3     51.6          D-----------      .0        .0

                                  VEHICLE INFORMATION

                VEHICLE #1                           VEHICLE #2
          (FRONT DAMAGE KNOWN)                 (REAR DAMAGE UNKNOWN)


SIZE------        4                     SIZE------        2
STIFFNESS-        4                     STIFFNESS-        1
SIDE------        F                     SIDE------        B
HANGL-----       .0 DEG                 HANGL-----     10.0 DEG
WEIGHT----   4600.0 LBS (2086.2 KG)     WEIGHT----   2530.0 LBS (1147.4 KG)
MASS------     11.905 LB-SEC**2/IN      MASS------      6.548 LB-SEC**2/IN
           ( 134.50 NT-SEC**2/CM)                 (  73.97 NT-SEC**2/CM)
RADIUS                                  RADIUS
GYRATION--  3741.0 IN**2                GYRATION--  2951.0 IN**2
         ( 24135.4 CM**2)                        ( 19038.7 CM**2)
```

RICSAC Test # 5; Vehicle 1 available; Vehicle 2 missing

```
      SUMMARY OF OLDMISPC RESULTS

RICSAC Test # 5; Vehicle 2 available; Vehicle 1 missing

                                       SPEED CHANGE (DAMAGE)

                          RESULTANT        LONGITUDINAL       LATERAL          PDOF
                          MPH   (KPH)      MPH    (KPH)     MPH    (KPH)       DEG

VEH #1 (ESTIMATED)     23.34 ( 37.56)  -23.34 (-37.56)     .00 (    .00)       .00
VEH #2 (KNOWN)         42.44 ( 68.29)   41.80 ( 67.25)   -7.37 (-11.86)    170.00


                               ENERGY                            FORCE
                            FT-LBS     (NT-M)                 LBS        (NT)

VEH #1 (ESTIMATED)       125610.9  (170288.8)             71065.0  (316097.1)
VEH #2 (KNOWN)           113152.8  (153399.4)             71065.0  (316097.1)
1
                                  SUMMARY OF DAMAGE DATA

               VEHICLE #1                               VEHICLE #2
      (ESTIMATED DAMAGE DIMENSION)             (KNOWN DAMAGE DIMENSION)
                      IN       (CM)                             IN       (CM)

L-----------      53.8    136.7          L-----------      53.0    134.6
C1----------      40.9    103.8          C1----------      36.0     91.4
C2----------      41.4    105.2          C2----------      36.5     92.7
C3----------      35.8     90.9          C3----------      31.5     80.0
C4----------      26.2     66.6          C4----------      23.0     58.4
C5----------      15.3     38.8          C5----------      13.3     33.8
C6----------       7.1     17.9          C6----------       6.0     15.2
D-----------        .0       .0          D-----------      -1.6     -4.1

                                     VEHICLE INFORMATION

                 VEHICLE #1                               VEHICLE #2
         (FRONT DAMAGE UNKNOWN)                   (REAR DAMAGE KNOWN)


SIZE------          4                     SIZE------          2
STIFFNESS-          4                     STIFFNESS-          1
SIDE------          F                     SIDE------          B
HANGL-----         .0 DEG                 HANGL-----       10.0 DEG
WEIGHT----    4600.0 LBS (2086.2 KG)      WEIGHT----    2530.0 LBS (1147.4 KG)
MASS------      11.905 LB-SEC**2/IN       MASS------       6.548 LB-SEC**2/IN
             ( 134.50 NT-SEC**2/CM)                    (  73.97 NT-SEC**2/CM)
RADIUS                                    RADIUS
GYRATION--    3741.0 IN**2                GYRATION--    2951.0 IN**2
         ( 24135.4 CM**2)                          ( 19038.7 CM**2)
```

RICSAC Test # 5; Vehicle 2 available; Vehicle 1 missing

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      SUMMARY OF OLDMISPC RESULTS

RICSAC Test # 6; Vehicle 1 available; Vehicle 2 missing

                                    SPEED CHANGE (DAMAGE)

                      RESULTANT        LONGITUDINAL       LATERAL        PDOF
                      MPH    (KPH)     MPH     (KPH)     MPH     (KPH)     DEG

VEH #1 (KNOWN)         6.99 ( 11.25)   -6.05 ( -9.74)    3.49 (  5.62)   330.00
VEH #2 (ESTIMATED)    11.41 ( 18.36)   -9.88 (-15.90)   -5.71 ( -9.19)    30.00

                            ENERGY                        FORCE
                        FT-LBS    (NT-M)                LBS      (NT)

VEH #1 (KNOWN)         14351.9  ( 19456.7)            25161.0  (111916.0)
VEH #2 (ESTIMATED)      7454.5  ( 10106.0)            25161.0  (111916.0)
1
                           SUMMARY OF DAMAGE DATA

            VEHICLE #1                           VEHICLE #2
   (KNOWN DAMAGE DIMENSION)              (ESTIMATED DAMAGE DIMENSION)
                 IN       (CM)                           IN       (CM)

L-----------    54.5    138.4           L-----------    48.4    122.8
C1----------      .5      1.3           C1----------     4.5     11.5
C2----------      .5      1.3           C2----------     4.5     11.5
C3----------     1.3      3.3           C3----------     5.0     12.7
C4----------     1.5      3.8           C4----------     5.1     13.0
C5----------     1.8      4.6           C5----------     5.3     13.4
C6----------     2.3      5.8           C6----------     5.6     14.2
D-----------     9.8     24.9           D-----------      .0       .0

                               VEHICLE INFORMATION

               VEHICLE #1                            VEHICLE #2
         (FRONT DAMAGE KNOWN)                  (SIDE DAMAGE UNKNOWN)


SIZE------       4                       SIZE------       1
STIFFNESS-       4                       STIFFNESS-       1
SIDE------       F                       SIDE------       R
HANGL-----      .0 DEG                   HANGL-----   120.0 DEG
WEIGHT----  4310.0 LBS (1954.6 KG)       WEIGHT----  2640.0 LBS (1197.3 KG)
MASS------    11.154 LB-SEC**2/IN        MASS------     6.832 LB-SEC**2/IN
           ( 126.02 NT-SEC**2/CM)                   (  77.19 NT-SEC**2/CM)
RADIUS                                   RADIUS
GYRATION--  3741.0 IN**2                 GYRATION--  2006.0 IN**2
         ( 24135.4 CM**2)                         ( 12941.9 CM**2)
```

RICSAC Test # 6; Vehicle 1 available; Vehicle 2 missing

```
      SUMMARY OF OLDMISPC RESULTS

RICSAC Test # 6; Vehicle 2 available; Vehicle 1 missing

                                   SPEED CHANGE (DAMAGE)

                      RESULTANT       LONGITUDINAL       LATERAL          PDOF
                      MPH   (KPH)     MPH     (KPH)     MPH    (KPH)      DEG

VEH #1 (ESTIMATED)   24.37 ( 39.21)  -21.11 (-33.96)   12.18 ( 19.60)   -30.00
VEH #2 (KNOWN)       39.79 ( 64.02)  -34.45 (-55.43)  -19.90 (-32.02)    30.00


                            ENERGY                             FORCE
                        FT-LBS    (NT-M)                    LBS       (NT)

VEH #1 (ESTIMATED)    183490.7  (248755.5)            95209.0  (423489.5)
VEH #2 (KNOWN)         68978.3  ( 93512.9)            93638.3  (416503.1)
1
                          SUMMARY OF DAMAGE DATA

            VEHICLE #1                           VEHICLE #2
   (ESTIMATED DAMAGE DIMENSION)          (KNOWN DAMAGE DIMENSION)
                 IN       (CM)                           IN       (CM)

L-----------    65.1    165.3          L-----------    77.0    195.6
C1----------    32.0     81.2          C1----------     4.0     10.2
C2----------    36.1     91.6          C2----------    12.0     30.5
C3----------    35.2     89.5          C3----------    17.9     45.5
C4----------    28.7     73.0          C4----------    19.3     49.0
C5----------    17.3     43.9          C5----------    17.0     43.2
C6----------     3.1      7.7          C6----------     8.3     21.1
D-----------      .0       .0          D-----------    -3.3     -8.4

                              VEHICLE INFORMATION

               VEHICLE #1                           VEHICLE #2
         (FRONT DAMAGE UNKNOWN)               (SIDE DAMAGE KNOWN)


SIZE------       4                      SIZE------       1
STIFFNESS-       4                      STIFFNESS-       1
SIDE------       F                      SIDE------       R
HANGL-----      .0 DEG                  HANGL-----   120.0 DEG
WEIGHT----  4310.0 LBS (1954.6 KG)      WEIGHT----  2640.0 LBS (1197.3 KG)
MASS------    11.154 LB-SEC**2/IN       MASS------     6.832 LB-SEC**2/IN
           ( 126.02 NT-SEC**2/CM)                  (  77.19 NT-SEC**2/CM)
RADIUS                                  RADIUS
GYRATION--  3741.0 IN**2                GYRATION--  2006.0 IN**2
         ( 24135.4 CM**2)                        ( 12941.9 CM**2)
```

RICSAC Test # 6; Vehicle 2 available; Vehicle 1 missing

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      SUMMARY OF OLDMISPC RESULTS

 RICSAC Test # 7; Vehicle 1 available; Vehicle 2 missing

                                          SPEED CHANGE (DAMAGE)

                          RESULTANT       LONGITUDINAL       LATERAL         PDOF
                          MPH   (KPH)     MPH     (KPH)     MPH     (KPH)      DEG

 VEH #1 (KNOWN)           8.91 ( 14.34)   -7.72 (-12.42)    4.45 (  7.17)   330.00
 VEH #2 (ESTIMATED)      14.71 ( 23.68)  -12.74 (-20.50)   -7.36 (-11.84)    30.00


                                ENERGY                           FORCE
                            FT-LBS    (NT-M)                 LBS       (NT)

 VEH #1 (KNOWN)            23273.6  ( 31551.6)             34977.7  (155581.0)
 VEH #2 (ESTIMATED)        11736.3  ( 15910.8)             34977.7  (155581.0)
1
                                   SUMMARY OF DAMAGE DATA

                 VEHICLE #1                                  VEHICLE #2
        (KNOWN DAMAGE DIMENSION)                   (ESTIMATED DAMAGE DIMENSION)
                         IN      (CM)                                IN      (CM)

 L-----------     66.0    167.6              L-----------     60.3    153.2
 C1----------       .0       .0              C1----------      4.0     10.2
 C2----------      1.3      3.3              C2----------      4.8     12.1
 C3----------      2.0      5.1              C3----------      5.2     13.2
 C4----------      3.8      9.7              C4----------      6.2     15.8
 C5----------      5.0     12.7              C5----------      6.9     17.6
 C6----------      6.3     16.0              C6----------      7.7     19.5
 D-----------      4.0     10.2              D-----------       .0       .0

                                      VEHICLE INFORMATION

                    VEHICLE #1                                 VEHICLE #2
              (FRONT DAMAGE KNOWN)                       (SIDE DAMAGE UNKNOWN)


 SIZE------        4                          SIZE------        1
 STIFFNESS-        4                          STIFFNESS-        1
 SIDE------        F                          SIDE------        R
 HANGL-----       .0 DEG                      HANGL-----   120.0 DEG
 WEIGHT----  4310.0 LBS (1954.6 KG)           WEIGHT----  2610.0 LBS (1183.7 KG)
 MASS------     11.154 LB-SEC**2/IN           MASS------      6.755 LB-SEC**2/IN
          ( 126.02 NT-SEC**2/CM)                        (  76.31 NT-SEC**2/CM)
 RADIUS                                       RADIUS
 GYRATION--  3741.0 IN**2                     GYRATION--  2006.0 IN**2
         ( 24135.4 CM**2)                             ( 12941.9 CM**2)
```

RICSAC Test # 7; Vehicle 1 available; Vehicle 2 missing

```
      SUMMARY OF OLDMISPC RESULTS

 RICSAC Test # 7; Vehicle 2 available; Vehicle 1 missing
                                           SPEED CHANGE (DAMAGE)

                         RESULTANT        LONGITUDINAL        LATERAL          PDOF
                         MPH   (KPH)      MPH     (KPH)      MPH     (KPH)      DEG

 VEH #1 (ESTIMATED)    33.75 ( 54.30)  -29.23 (-47.03)   16.87 ( 27.15)   -30.00
 VEH #2 (KNOWN)        55.73 ( 89.67)  -48.26 (-77.65)  -27.88 (-44.85)    30.00


                              ENERGY                          FORCE
                           FT-LBS     (NT-M)               LBS       (NT)

 VEH #1 (ESTIMATED)     377983.9  (512426.8)            148958.7  (662568.2)
 VEH #2 (KNOWN)         108606.7  (147236.4)            136164.3  (605658.8)
1
                                      SUMMARY OF DAMAGE DATA

             VEHICLE #1                                  VEHICLE #2
      (ESTIMATED DAMAGE DIMENSION)               (KNOWN DAMAGE DIMENSION)
                    IN      (CM)                                IN       (CM)

 L-----------     77.0    195.6             L-----------    108.5     275.6
 C1----------     51.5    130.7             C1----------       .5       1.3
 C2----------     50.9    129.3             C2----------     11.0      27.9
 C3----------     47.1    119.7             C3----------     17.8      45.2
 C4----------     39.9    101.3             C4----------     21.0      53.3
 C5----------     27.1     68.8             C5----------     21.3      54.1
 C6----------      8.9     22.7             C6----------      7.3      18.5
 D-----------       .0       .0             D-----------     -8.5     -21.6

  (DOFF ADJUSTED    .0 INCHES
  TO MATCH VEHICLE DIMENSION)

                                          VEHICLE INFORMATION

                VEHICLE #1                                  VEHICLE #2
          (FRONT DAMAGE UNKNOWN)                       (SIDE DAMAGE KNOWN)


 SIZE------        4                         SIZE------        1
 STIFFNESS-        4                         STIFFNESS-        1
 SIDE------        F                         SIDE------        R
 HANGL-----       .0 DEG                     HANGL-----    120.0 DEG
 WEIGHT----   4310.0 LBS (1954.6 KG)         WEIGHT----   2610.0 LBS (1183.7 KG)
 MASS------     11.154 LB-SEC**2/IN          MASS------      6.755 LB-SEC**2/IN
             ( 126.02 NT-SEC**2/CM)                     (  76.31 NT-SEC**2/CM)
 RADIUS                                      RADIUS
 GYRATION--   3741.0 IN**2                   GYRATION--   2006.0 IN**2
           ( 24135.4 CM**2)                            ( 12941.9 CM**2)
```

RICSAC Test # 7; Vehicle 2 available; Vehicle 1 missing

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      SUMMARY OF OLDMISPC RESULTS

RICSAC Test # 8; Vehicle 1 available; Vehicle 2 missing

                                      SPEED CHANGE (DAMAGE)

                        RESULTANT        LONGITUDINAL       LATERAL          PDOF
                        MPH   (KPH)      MPH     (KPH)     MPH     (KPH)      DEG

VEH #1 (KNOWN)        11.99 ( 19.30)   -8.48 (-13.65)    8.48 ( 13.64)    315.00
VEH #2 (ESTIMATED)    11.41 ( 18.35)   -8.06 (-12.98)   -8.07 (-12.98)     45.00


                              ENERGY                          FORCE
                          FT-LBS     (NT-M)                 LBS       (NT)

VEH #1 (KNOWN)           27664.3   ( 37504.0)             40190.8   (178768.8)
VEH #2 (ESTIMATED)       18552.6   ( 25151.5)             40190.8   (178768.8)
1
                                 SUMMARY OF DAMAGE DATA

               VEHICLE #1                                 VEHICLE #2
     (KNOWN DAMAGE DIMENSION)                  (ESTIMATED DAMAGE DIMENSION)
                      IN      (CM)                                 IN      (CM)

L-----------       73.0     185.4          L-----------       73.0     185.4
C1----------        2.7       6.9          C1----------        6.0      15.3
C2----------        3.6       9.1          C2----------        6.6      16.9
C3----------         .0        .0          C3----------        4.2      10.7
C4----------         .0        .0          C4----------        4.2      10.7
C5----------         .0        .0          C5----------        4.2      10.7
C6----------         .0        .0          C6----------        4.2      10.7
D-----------         .0        .0          D-----------         .0        .0

                                     VEHICLE INFORMATION

                VEHICLE #1                                 VEHICLE #2
          (FRONT DAMAGE KNOWN)                       (SIDE DAMAGE UNKNOWN)


SIZE------         4                        SIZE------         4
STIFFNESS-         4                        STIFFNESS-         4
SIDE------         F                        SIDE------         R
HANGL-----        .0 DEG                    HANGL-----      90.0 DEG
WEIGHT----   4480.0 LBS (2031.7 KG)         WEIGHT----   4710.0 LBS (2136.1 KG)
MASS------     11.594 LB-SEC**2/IN          MASS------     12.189 LB-SEC**2/IN
            ( 130.99 NT-SEC**2/CM)                      ( 137.72 NT-SEC**2/CM)
RADIUS                                      RADIUS
GYRATION--  3741.0 IN**2                    GYRATION--  3741.0 IN**2
         ( 24135.4 CM**2)                            ( 24135.4 CM**2)
```

RICSAC Test # 8; Vehicle 1 available; Vehicle 2 missing

```
      SUMMARY OF OLDMISPC RESULTS

RICSAC Test # 8; Vehicle 2 available; Vehicle 1 missing

                                             SPEED CHANGE (DAMAGE)

                        RESULTANT        LONGITUDINAL       LATERAL        PDOF
                       MPH   (KPH)      MPH    (KPH)     MPH    (KPH)      DEG

VEH #1 (ESTIMATED)    16.81 ( 27.05)  -11.89 (-19.13)   11.89 ( 19.13)   -45.00
VEH #2 (KNOWN)        15.99 ( 25.73)  -11.31 (-18.19)  -11.31 (-18.20)    45.00


                              ENERGY                           FORCE
                         FT-LBS    (NT-M)                  LBS      (NT)

VEH #1 (ESTIMATED)      55141.6  ( 74754.6)              57882.1  (257459.6)
VEH #2 (KNOWN)          31342.6  ( 42490.7)              54904.0  (244213.1)
1
                                  SUMMARY OF DAMAGE DATA

             VEHICLE #1                                  VEHICLE #2
     (ESTIMATED DAMAGE DIMENSION)              (KNOWN DAMAGE DIMENSION)
                    IN      (CM)                                IN      (CM)

L-----------      77.0     195.6           L-----------      84.5     214.6
C1----------       4.3      10.8           C1----------       6.2      15.7
C2----------       7.4      18.8           C2----------       8.3      21.1
C3----------       8.9      22.6           C3----------       9.2      23.4
C4----------       5.3      13.5           C4----------       6.0      15.2
C5----------       2.2       5.7           C5----------       4.4      11.2
C6----------        .0        .0           C6----------        .8       2.0
D-----------        .0        .0           D-----------      15.0      38.1

 (DOFF ADJUSTED    .0 INCHES
 TO MATCH VEHICLE DIMENSION)

                                      VEHICLE INFORMATION

                VEHICLE #1                                VEHICLE #2
         (FRONT DAMAGE UNKNOWN)                    (SIDE DAMAGE KNOWN)


SIZE------          4                       SIZE------          4
STIFFNESS-          4                       STIFFNESS-          4
SIDE------          F                       SIDE------          R
HANGL-----         .0 DEG                   HANGL-----      90.0 DEG
WEIGHT----   4480.0 LBS (2031.7 KG)         WEIGHT----   4710.0 LBS (2136.1 KG)
MASS------     11.594 LB-SEC**2/IN          MASS------     12.189 LB-SEC**2/IN
           ( 130.99 NT-SEC**2/CM)                      ( 137.72 NT-SEC**2/CM)
RADIUS                                      RADIUS
GYRATION--   3741.0 IN**2                   GYRATION--   3741.0 IN**2
         ( 24135.4 CM**2)                            ( 24135.4 CM**2)
```

RICSAC Test # 8; Vehicle 2 available; Vehicle 1 missing

```
      SUMMARY OF OLDMISPC RESULTS

 RICSAC Test # 9; Vehicle 1 available; Vehicle 2 missing

                                            SPEED CHANGE (DAMAGE)

                             RESULTANT        LONGITUDINAL        LATERAL          PDOF
                             MPH   (KPH)      MPH     (KPH)      MPH     (KPH)      DEG

 VEH #1 (KNOWN)            27.88 ( 44.86)  -19.72 (-31.73)   19.71 ( 31.72)   315.00
 VEH #2 (ESTIMATED)        12.84 ( 20.66)   -9.08 (-14.60)   -9.08 (-14.61)    45.00


                                 ENERGY                        FORCE
                               FT-LBS    (NT-M)              LBS       (NT)

 VEH #1 (KNOWN)              51250.0  ( 69478.8)           47966.9  (213356.9)
 VEH #2 (ESTIMATED)          38640.9  ( 52384.8)           47966.9  (213356.9)
1
                                   SUMMARY OF DAMAGE DATA

            VEHICLE #1                                    VEHICLE #2
    (KNOWN DAMAGE DIMENSION)                      (ESTIMATED DAMAGE DIMENSION)
                  IN       (CM)                                  IN       (CM)

 L-----------    49.8    126.5          L-----------    49.8    126.5
 C1----------     5.0     12.7          C1----------     8.3     21.2
 C2----------     5.8     14.7          C2----------     8.9     22.7
 C3----------    12.5     31.8          C3----------    14.0     35.5
 C4----------     7.5     19.0          C4----------    10.2     26.0
 C5----------     7.5     19.0          C5----------    10.2     26.0
 C6----------     9.5     24.1          C6----------    11.7     29.8
 D-----------     1.6      4.1          D-----------      .0       .0

                                       VEHICLE INFORMATION

               VEHICLE #1                                   VEHICLE #2
          (FRONT DAMAGE KNOWN)                         (SIDE DAMAGE UNKNOWN)


 SIZE------        1                       SIZE------        4
 STIFFNESS-        9                       STIFFNESS-        4
 SIDE------        F                       SIDE------        R
 HANGL-----       .0 DEG                   HANGL-----     90.0 DEG
 WEIGHT----   2270.0 LBS (1029.5 KG)       WEIGHT----   4930.0 LBS (2235.8 KG)
 MASS------      5.875 LB-SEC**2/IN        MASS------     12.759 LB-SEC**2/IN
            (  66.37 NT-SEC**2/CM)                    ( 144.15 NT-SEC**2/CM)
 RADIUS                                    RADIUS
 GYRATION--   2006.0 IN**2                 GYRATION--   3741.0 IN**2
          ( 12941.9 CM**2)                          ( 24135.4 CM**2)
```

RICSAC Test # 9; Vehicle 1 available; Vehicle 2 missing

```
      SUMMARY OF OLDMISPC RESULTS

RICSAC Test # 9; Vehicle 2 available; Vehicle 1 missing

                                          SPEED CHANGE (DAMAGE)

                       RESULTANT       LONGITUDINAL       LATERAL          PDOF
                       MPH   (KPH)     MPH     (KPH)     MPH    (KPH)      DEG

VEH #1 (ESTIMATED)   16.18 ( 26.03)  -11.44 (-18.41)   11.44 ( 18.40)   -45.00
VEH #2 (KNOWN)        7.45 ( 11.99)   -5.27 ( -8.47)   -5.27 ( -8.48)    45.00


                            ENERGY                         FORCE
                         FT-LBS    (NT-M)                 LBS        (NT)

VEH #1 (ESTIMATED)      18539.5   ( 25133.7)            30213.7  (134390.6)
VEH #2 (KNOWN)          11288.7   ( 15303.9)            26672.5  (118639.3)
1
                                   SUMMARY OF DAMAGE DATA

             VEHICLE #1                             VEHICLE #2
     (ESTIMATED DAMAGE DIMENSION)           (KNOWN DAMAGE DIMENSION)
                      IN      (CM)                           IN      (CM)

L-----------      54.5    138.4          L-----------    54.5    138.4
C1----------       4.3     10.9          C1----------     7.8     19.8
C2----------        .0       .1          C2----------     4.6     11.7
C3----------        .3       .8          C3----------     4.8     12.2
C4----------        .0       .0          C4----------     3.3      8.4
C5----------        .0       .0          C5----------     2.8      7.1
C6----------        .0       .0          C6----------     1.5      3.8
D-----------        .0       .0          D-----------    68.0    172.7

                                     VEHICLE INFORMATION

                VEHICLE #1                              VEHICLE #2
        (FRONT DAMAGE UNKNOWN)                  (SIDE DAMAGE KNOWN)


SIZE------        1                       SIZE------        4
STIFFNESS-        9                       STIFFNESS-        4
SIDE------        F                       SIDE------        R
HANGL-----       .0 DEG                   HANGL-----     90.0 DEG
WEIGHT----   2270.0 LBS (1029.5 KG)       WEIGHT----   4930.0 LBS (2235.8 KG)
MASS------        5.875 LB-SEC**2/IN      MASS------       12.759 LB-SEC**2/IN
             (  66.37 NT-SEC**2/CM)                    ( 144.15 NT-SEC**2/CM)
RADIUS                                    RADIUS
GYRATION--   2006.0 IN**2                 GYRATION--   3741.0 IN**2
          ( 12941.9 CM**2)                          ( 24135.4 CM**2)
```

RICSAC Test # 9; Vehicle 2 available; Vehicle 1 missing

```
      SUMMARY OF OLDMISPC RESULTS

RICSAC Test #10; Vehicle 1 available; Vehicle 2 missing

                                           SPEED CHANGE (DAMAGE)

                      RESULTANT        LONGITUDINAL       LATERAL         PDOF
                      MPH   (KPH)      MPH    (KPH)      MPH    (KPH)      DEG

VEH #1 (KNOWN)       28.87 ( 46.44)  -20.41 (-32.85)   20.41 ( 32.84)   315.00
VEH #2 (ESTIMATED)   14.10 ( 22.68)   -9.97 (-16.04)   -9.97 (-16.04)    45.00

                            ENERGY                         FORCE
                        FT-LBS    (NT-M)                LBS      (NT)

VEH #1 (KNOWN)          57428.9  ( 77855.5)            49605.5  (220645.4)
VEH #2 (ESTIMATED)      43299.6  ( 58700.6)            49605.5  (220645.4)
1
                                 SUMMARY OF DAMAGE DATA

            VEHICLE #1                                  VEHICLE #2
   (KNOWN DAMAGE DIMENSION)                   (ESTIMATED DAMAGE DIMENSION)
                  IN      (CM)                                IN      (CM)

L-----------    47.5    120.7              L-----------    47.5    120.7
C1----------     7.0     17.8              C1----------     9.8     25.0
C2----------    10.2     25.9              C2----------    12.3     31.1
C3----------    14.0     35.6              C3----------    15.1     38.4
C4----------     8.9     22.6              C4----------    11.3     28.6
C5----------     7.0     17.8              C5----------     9.8     25.0
C6----------     9.0     22.9              C6----------    11.3     28.8
D-----------    -2.8     -7.1              D-----------      .0       .0

                                     VEHICLE INFORMATION

               VEHICLE #1                                 VEHICLE #2
         (FRONT DAMAGE KNOWN)                       (SIDE DAMAGE UNKNOWN)


SIZE------        1                         SIZE------        4
STIFFNESS-        9                         STIFFNESS-        4
SIDE------        F                         SIDE------        R
HANGL-----       .0 DEG                     HANGL-----     90.0 DEG
WEIGHT----  2320.0 LBS (1052.2 KG)          WEIGHT----  4750.0 LBS (2154.2 KG)
MASS------      6.004 LB-SEC**2/IN          MASS------      12.293 LB-SEC**2/IN
          (   67.83 NT-SEC**2/CM)                     ( 138.89 NT-SEC**2/CM)
RADIUS                                      RADIUS
GYRATION--  2006.0 IN**2                    GYRATION--  3741.0 IN**2
         ( 12941.9 CM**2)                            ( 24135.4 CM**2)
```

RICSAC Test # 10; Vehicle 1 available; Vehicle 2 missing

```
      SUMMARY OF OLDMISPC RESULTS

RICSAC Test #10; Vehicle 2 available; Vehicle 1 missing

                                            SPEED CHANGE (DAMAGE)

                           RESULTANT        LONGITUDINAL        LATERAL           PDOF
                           MPH    (KPH)     MPH     (KPH)      MPH     (KPH)      DEG

VEH #1 (ESTIMATED)      18.09 ( 29.11)  -12.79 (-20.59)   12.79 ( 20.58)    -45.00
VEH #2 (KNOWN)           8.84 ( 14.22)   -6.25 (-10.05)   -6.25 (-10.05)     45.00


                                 ENERGY                          FORCE
                             FT-LBS    (NT-M)                 LBS        (NT)

VEH #1 (ESTIMATED)          22811.8  ( 30925.6)             32884.6  (146270.9)
VEH #2 (KNOWN)              16067.3  ( 21782.2)             31301.9  (139230.7)
1
                                   SUMMARY OF DAMAGE DATA

               VEHICLE #1                               VEHICLE #2
    (ESTIMATED DAMAGE DIMENSION)             (KNOWN DAMAGE DIMENSION)
                      IN       (CM)                                IN        (CM)

L-----------        53.0     134.6           L-----------        53.0     134.6
C1----------         6.1      15.6           C1----------         9.2      23.4
C2----------         2.6       6.5           C2----------         6.5      16.5
C3----------         2.0       5.2           C3----------         6.1      15.5
C4----------         1.0       2.5           C4----------         5.3      13.5
C5----------          .0        .0           C5----------         4.5      11.4
C6----------          .0        .0           C6----------          .5       1.3
D-----------          .0        .0           D-----------        66.5     168.9

                                       VEHICLE INFORMATION

                  VEHICLE #1                                 VEHICLE #2
         (FRONT DAMAGE UNKNOWN)                      (SIDE DAMAGE KNOWN)


SIZE------         1                         SIZE------         4
STIFFNESS-         9                         STIFFNESS-         4
SIDE------         F                         SIDE------         R
HANGL-----        .0 DEG                     HANGL-----      90.0 DEG
WEIGHT----    2320.0 LBS (1052.2 KG)         WEIGHT----    4750.0 LBS (2154.2 KG)
MASS------      6.004 LB-SEC**2/IN           MASS------      12.293 LB-SEC**2/IN
             (  67.83 NT-SEC**2/CM)                       ( 138.89 NT-SEC**2/CM)
RADIUS                                       RADIUS
GYRATION--   2006.0 IN**2                    GYRATION--   3741.0 IN**2
         ( 12941.9 CM**2)                             ( 24135.4 CM**2)
```

RICSAC Test # 10; Vehicle 2 available; Vehicle 1 missing

```
     SUMMARY OF OLDMISPC RESULTS

 RICSAC Test #11; Vehicle 1 available; Vehicle 2 missing

                                         SPEED CHANGE (DAMAGE)

                           RESULTANT       LONGITUDINAL       LATERAL          PDOF
                           MPH   (KPH)     MPH    (KPH)     MPH    (KPH)       DEG

 VEH #1 (KNOWN)          20.88 ( 33.60)  -20.80 (-33.47)   -1.82 ( -2.93)      5.00
 VEH #2 (ESTIMATED)      13.09 ( 21.07)  -13.04 (-20.98)    1.16 (  1.86)    355.00


                                 ENERGY                          FORCE
                             FT-LBS    (NT-M)                  LBS       (NT)

 VEH #1 (KNOWN)            33112.8   ( 44890.4)             33197.0   (147660.2)
 VEH #2 (ESTIMATED)        42978.8   ( 58265.6)             33197.0   (147660.2)
1
                                  SUMMARY OF DAMAGE DATA

           VEHICLE #1                                     VEHICLE #2
   (KNOWN DAMAGE DIMENSION)                      (ESTIMATED DAMAGE DIMENSION)
                  IN       (CM)                                  IN       (CM)

 L-----------    32.5      82.5               L-----------     32.0      81.3
 C1----------    22.0      55.9               C1----------     13.5      34.3
 C2----------    20.2      51.3               C2----------     16.7      42.5
 C3----------    18.5      47.0               C3----------     19.1      48.4
 C4----------    16.8      42.7               C4----------     21.3      54.0
 C5----------    15.0      38.1               C5----------     23.5      59.6
 C6----------    12.5      31.8               C6----------     25.8      65.6
 D-----------   -12.8     -32.5               D-----------       .0        .0

                                      VEHICLE INFORMATION

              VEHICLE #1                                    VEHICLE #2
        (FRONT DAMAGE KNOWN)                          (FRONT DAMAGE UNKNOWN)


 SIZE------        2                           SIZE------        4
 STIFFNESS-        2                           STIFFNESS-        4
 SIDE------        F                           SIDE------        F
 HANGL-----       .0 DEG                       HANGL-----    190.0 DEG
 WEIGHT----   3060.0 LBS (1387.8 KG)           WEIGHT----   4880.0 LBS (2213.2 KG)
 MASS------      7.919 LB-SEC**2/IN            MASS------     12.629 LB-SEC**2/IN
            (  89.47 NT-SEC**2/CM)                        ( 142.69 NT-SEC**2/CM)
 RADIUS                                        RADIUS
 GYRATION--  2951.0 IN**2                      GYRATION--  3741.0 IN**2
         ( 19038.7 CM**2)                               ( 24135.4 CM**2)
```

RICSAC Test # 11; Vehicle 1 available; Vehicle 2 missing

```
      SUMMARY OF OLDMISPC RESULTS

RICSAC Test #11; Vehicle 2 available; Vehicle 1 missing
                                   SPEED CHANGE (DAMAGE)

                      RESULTANT       LONGITUDINAL       LATERAL         PDOF
                      MPH   (KPH)     MPH     (KPH)     MPH     (KPH)    DEG

VEH #1 (ESTIMATED)   22.09 ( 35.55)  -22.01 (-35.41)   -1.93 ( -3.10)    5.00
VEH #2 (KNOWN)       13.85 ( 22.29)  -13.80 (-22.20)    1.21 (  1.94)  355.00


                            ENERGY                         FORCE
                        FT-LBS    (NT-M)                LBS      (NT)

VEH #1 (ESTIMATED)     36096.8  ( 48935.9)          35013.2  (155738.7)
VEH #2 (KNOWN)         46842.1  ( 63503.1)          35013.2  (155738.7)
1
                          SUMMARY OF DAMAGE DATA

            VEHICLE #1                            VEHICLE #2
   (ESTIMATED DAMAGE DIMENSION)           (KNOWN DAMAGE DIMENSION)
                 IN       (CM)                            IN       (CM)

L-----------    33.8     85.9          L-----------    33.3     84.6
C1----------    10.6     26.9          C1----------    29.2     74.2
C2----------    13.1     33.2          C2----------    26.3     66.8
C3----------    16.5     42.0          C3----------    23.0     58.4
C4----------    19.8     50.4          C4----------    18.7     47.5
C5----------    22.4     56.8          C5----------    14.2     36.1
C6----------    24.6     62.5          C6----------    11.0     27.9
D-----------      .0       .0          D-----------   -12.9    -32.8

                              VEHICLE INFORMATION

               VEHICLE #1                            VEHICLE #2
         (FRONT DAMAGE UNKNOWN)                (FRONT DAMAGE KNOWN)


SIZE------       2                      SIZE------       4
STIFFNESS-       2                      STIFFNESS-       4
SIDE------       F                      SIDE------       F
HANGL-----      .0 DEG                  HANGL-----   190.0 DEG
WEIGHT----  3060.0 LBS (1387.8 KG)      WEIGHT----  4880.0 LBS (2213.2 KG)
MASS------     7.919 LB-SEC**2/IN       MASS------     12.629 LB-SEC**2/IN
           (  89.47 NT-SEC**2/CM)                  ( 142.69 NT-SEC**2/CM)
RADIUS                                  RADIUS
GYRATION--  2951.0 IN**2                GYRATION--  3741.0 IN**2
         ( 19038.7 CM**2)                        ( 24135.4 CM**2)
```

RICSAC Test # 11; Vehicle 2 available; Vehicle 1 missing

```
     SUMMARY OF OLDMISPC RESULTS

 RICSAC Test #12; Vehicle 1 available; Vehicle 2 missing

                                          SPEED CHANGE (DAMAGE)

                       RESULTANT       LONGITUDINAL       LATERAL          PDOF
                       MPH    (KPH)    MPH     (KPH)     MPH     (KPH)      DEG

 VEH #1 (KNOWN)       29.12 ( 46.86)  -29.01 (-46.68)   -2.54 ( -4.08)     5.00
 VEH #2 (ESTIMATED)   20.21 ( 32.51)  -20.13 (-32.39)    1.78 (  2.87)   355.00


                             ENERGY                          FORCE
                         FT-LBS    (NT-M)                 LBS       (NT)

 VEH #1 (KNOWN)          66974.1  ( 90795.8)            46119.0  (205137.2)
 VEH #2 (ESTIMATED)      84291.3  (114272.4)            46119.0  (205137.2)
1
                                  SUMMARY OF DAMAGE DATA

           VEHICLE #1                                 VEHICLE #2
    (KNOWN DAMAGE DIMENSION)                  (ESTIMATED DAMAGE DIMENSION)
                  IN       (CM)                                IN       (CM)

 L-----------    32.0      81.3            L-----------    32.5      82.5
 C1----------    38.6      98.0            C1----------    15.0      38.2
 C2----------    34.6      87.9            C2----------    21.7      55.1
 C3----------    29.5      74.9            C3----------    29.7      75.6
 C4----------    26.0      66.0            C4----------    34.2      86.7
 C5----------    19.6      49.8            C5----------    40.6     103.0
 C6----------    14.3      36.3            C6----------    45.6     115.8
 D-----------     2.8       7.1            D-----------      .0        .0

                                     VEHICLE INFORMATION

              VEHICLE #1                                VEHICLE #2
        (FRONT DAMAGE KNOWN)                      (FRONT DAMAGE UNKNOWN)


 SIZE------        2                         SIZE------        4
 STIFFNESS-        2                         STIFFNESS-        4
 SIDE------        F                         SIDE------        F
 HANGL-----       .0 DEG                     HANGL-----    190.0 DEG
 WEIGHT----   3150.0 LBS (1428.6 KG)         WEIGHT----   4540.0 LBS (2059.0 KG)
 MASS------      8.152 LB-SEC**2/IN          MASS------     11.750 LB-SEC**2/IN
            (   92.10 NT-SEC**2/CM)                     ( 132.75 NT-SEC**2/CM)
 RADIUS                                      RADIUS
 GYRATION--  2951.0 IN**2                    GYRATION--  3741.0 IN**2
          ( 19038.7 CM**2)                           ( 24135.4 CM**2)
```

RICSAC Test # 12; Vehicle 1 available; Vehicle 2 missing

```
      SUMMARY OF OLDMISPC RESULTS

RICSAC Test #12; Vehicle 2 available; Vehicle 1 missing
                                   SPEED CHANGE (DAMAGE)

                      RESULTANT       LONGITUDINAL       LATERAL         PDOF
                      MPH   (KPH)     MPH    (KPH)     MPH    (KPH)      DEG

VEH #1 (ESTIMATED)   23.57 ( 37.92)  -23.48 (-37.78)   -2.05 ( -3.30)     5.00
VEH #2 (KNOWN)       16.35 ( 26.31)  -16.29 (-26.21)    1.42 (  2.29)   355.00

                            ENERGY                         FORCE
                        FT-LBS    (NT-M)                LBS       (NT)

VEH #1 (ESTIMATED)     43753.6   ( 59316.1)           35497.9  (157894.7)
VEH #2 (KNOWN)         56778.2   ( 76973.3)           35497.9  (157894.7)
1
                          SUMMARY OF DAMAGE DATA

            VEHICLE #1                           VEHICLE #2
   (ESTIMATED DAMAGE DIMENSION)           (KNOWN DAMAGE DIMENSION)
                 IN       (CM)                            IN       (CM)

L-----------    28.7      73.0           L-----------    28.3      71.9
C1----------    13.9      35.3           C1----------    39.5     100.3
C2----------    16.9      42.9           C2----------    33.0      83.8
C3----------    20.4      51.9           C3----------    28.8      73.2
C4----------    24.3      61.7           C4----------    23.8      60.5
C5----------    27.5      70.0           C5----------    19.2      48.8
C6----------    32.5      82.7           C6----------    15.3      38.9
D-----------      .0        .0           D-----------   -10.6     -26.9

                              VEHICLE INFORMATION

               VEHICLE #1                            VEHICLE #2
         (FRONT DAMAGE UNKNOWN)                (FRONT DAMAGE KNOWN)


SIZE------         3                    SIZE------         4
STIFFNESS-         2                    STIFFNESS-         4
SIDE------         F                    SIDE------         F
HANGL-----        .0 DEG                HANGL-----     190.0 DEG
WEIGHT----    3150.0 LBS (1428.6 KG)    WEIGHT----    4540.0 LBS (2059.0 KG)
MASS------      8.152 LB-SEC**2/IN      MASS------      11.750 LB-SEC**2/IN
           (   92 10 NT-SEC**2/CM)                 ( 132.75 NT-SEC**2/CM)
RADIUS                                  RADIUS
GYRATION--    2951.0 IN**2              GYRATION--    3741.0 IN**2
         ( 19038.7 CM**2)                        ( 24135.4 CM**2)
```

RICSAC Test # 12; Vehicle 2 available; Vehicle 1 missing

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